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ORIGINAL ARTICLES

*A RESUME OF STUDIES ON WHEATS IN MALWA

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(Received for publication on 14 August 1953)

(With two text figures)

Introduction

MALWA is an important wheat-growing tract of the Indian Union. It is famous for growing wheat on account of its heavy black soil which is very retentive of moisture, and also because of its geographical situation whereby it receives rainfall from both the monsoons. The wheat originally grown was of the *Malvi* type (T. *durum*) which is slow-growing and thrives well under *barani* conditions, but after the famine of 1899 *Pissi* wheats (T. *vulgare*) were introduced from time to time. Though these wheats have not been able to compete with Malvi *durums* under *barani* conditions, under irrigated conditions, however, their cultivation has been well established. The total area under wheat in Malwa is about 11 lakh acres, and the above-mentioned two species are extensively grown both under irrigated and non-irrigated conditions. The grains of *vulgare* wheat are usually of medium size and are white or red in colour while the kernel structure ranges from soft to hard. The endosperm of soft grains is friable and starchy in appearance. Endosperm of hard types is translucent. Grains of the *durum* varieties are long, plumpy, hard and flinty. They have high gluten content and are not only preferred for making *suji* and *sewayan* but are also liked by the local Malvis for making good *chapatis*, as these *chapatis* do not get hard if kept for a few hours. Table I gives the physical and chemical characters of these two species.

Table I

Physical and chemical characters of T. vulgare *and* T. durum

Species	Bushel weight	Weight of 1000 grains	Moisture (per cent)	Dry gluten (per cent)
T. *vulgare*	63·2 lb.	38·5 gm.	9·6	8·5
T. *durum*	63·1 lb.	44·9 gm.	11·2	9·9

*The work described in the article was carried out during the period 1932-1951 when experiments on replicated randomized layouts were first introduced at the Institute. With the discontinuation of work on all aspects of wheat problem since 1951 when a Wheat Rust Co-ordinated Scheme was started at Indore under the joint control of the Director of this Institute and the Head of the Division of Botany, Indian Agricultural Research Institute, New Delhi, the author who had carried out several experiments himself, thought it desirable to write up the results so far achieved at the Institute.

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Distribution

(i) *T. vulgare.* The proportion of white *vulgare* wheats is very high in areas around Bhopal while that of red soft wheat is high around Indore. In other areas a mixture of red and white wheats is grown. It is generally grown interspersed with white in varying proportions.

(ii) *T. durum.* White or amber *durum* is very extensively grown in Malwa. The proportion of white *durum* to the total crop ranges from 30 per cent in Dhar to nearly 90 per cent in Dewas. In the south the proportion ranges between 10-20 per cent, while about 50 per cent of the crop consists of red *durums*.

Method of cultivation

Wheat is generally grown as an unirrigated crop in Malwa. The fields are ploughed with *bakhar* three or four times during summer, and, after the rains have started, sann hemp (*Crotolaria juncea*) is often sown in fields, where wheat is to be grown in the ensuing *rabi* season, at the rate of 80 lb. of seed per acre for green manuring. When the crop is about 8-10 weeks old, it is ploughed in by means of an iron plough. The fields are then ploughed with *bakhar* twice or thrice before the wheat is sown. Sowing is done by an iron tined two-coultered seed drill with tines 14 in. apart. The usual seed rate is 60 lb. and 80 lb. per acre under *barani* and irrigated conditions respectively. After the crop is sown and seeds covered by a wooden beam, no interculture or weeding is done. The crop gets ready for harvest by the middle of March. The average yield under *barani* condition is about 500-600 lb. per acre. Under irrigated conditions, the crop is irrigated once at the earing stage and again at the milky stage of the ears. The yield varies from 1,000 to 1,200 lb. per acre.

PLANT BREEDING

One of the methods of improvement of a crop in a given area is the introduction of 'ready made' strains from outside and testing their suitability to local conditions in that area. The introduction of improved strains of wheat in States in Central India was given considerable attention since 1932 at the Institute of Plant Industry, Indore, which served as a centre for agricultural investigations for those States.

A scheme for testing of improved strains of *T. vulgare* and *T. durum* was carried out by the Institute from 1932-33. The results of these investigations have been reported by Hutchinson and Panse [1936]. As a result of a very large number of experiments carried out according to modern methods of field experimentation in different parts of Madhya Bharat, they came to the conclusion that no improved strains from outside could be recommended as superior to the local types for unirrigated conditions ; under irrigated conditions, however, 'C 591' proved superior and was preferred for its better quality.

The necessity, therefore, for evolving wheat strains suited to local conditions in Central India became evident. A beginning was thus made in 1934 by making single plant selections from different wheat-growing areas of Madhya Bharat and were later compared with locals at the Institute for four seasons, 1936-1939.

TABLE II

Comparative performances of selected strains against locals
(pounds per acre)

Strains	1936-37	1937-38	1938-39	1939-40
EK-69	1,108 lb.	..	553 lb.	957 lb.
B-14	1,217 lb.	936 lb.	528 lb.	795 lb.
EK-70	..	..	513 lb.	..
R-42	1,281 lb.	809 lb.	..	..
EK-118	1,091 lb.	..	537 lb.	944 lb.
R-14	1,440 lb.	856 lb.	472 lb.	..
N-111	..	..	500 lb.	..
N-24	..	..	..	941 lb.
Mixture 14 and 42	..	821 lb.	..	818 lb.
Mixture 70 and 118	..	..	476 lb.	..
Malvi local	1,106 lb.	886 lb.	517 lb.	997 lb.
Dhar local	1,097 lb.	931 lb.	532 lb.	1,012 lb.
Significant difference	201 lb.	..	..	110 lb.

Of the above selections, 'R-14' a red-grained wheat was found to be significantly superior in one out of three seasons to local Malvi, but because of its red colour of grains, it was valued 15-25 per cent less. Another white-grained strain called 'EK-69' was valued higher though it was not as good in yield as 'R-14' but was liked by the traders on account of its good grains.

Selection in *T. vulgare* wheats resulted in 'N-24' which gave as high yield as *Pissi* local but not significantly higher. These were being tested year after year with other provincial *vulgare* wheats. 'C 591' continued to be recommended to the cultivators.

One of the selections from Narsingarh State, which belonged to *T. turgidum* group, was found to possess a very attractive look, and hard and flinty grains. *Turgidum* species are known to have soft and mealy grains. The strain was called 'N-111' and though did not give as good yield as the local *durum*, fetched a premium of 10 per cent in the market for its superior grains.

These selections, however, did not lead to very successful results and hence another attempt was made in 1939 to collect single plants from Malvi wheat-growing areas of Dhar and Dewas States. One hundred and thirty-four single plants were brought and tested at the Institute in subsequent years. A few progeny bulks, namely, 'F.16,' 'F.37' and 'F.72,' were developed. Of these, 'F.16' gave significantly higher yield of grain than *Malvi* local in two out of three seasons.

TABLE III

Performances of a few progeny bulks against local
(Yield in pounds per acre)

Strains	1943-44	1944-45	1945-46
F.16	677	518	731
F.37	652	542	740
F.72	601	474	679
1940 bulk	648	..	..
R-42	510	503	675
P.B 1	..	566	786
P.B 3	..	483	752
EK 69	..	494	739
Bombay 224	..	479	687
Niphad 4	..	..	582
Malvi Local	584	464	755
Significant difference	78	48	71
S. E. per cent	4·3	3·6	3·5

Side by side with selection work, a scheme of hybridisation was started and with the kind co-operation of Dr. O. H. Frankel of Wheat Research Institute, New Zealand, crosses were made in 1938 between Malvi *durums* and Cambridge Rivet (T. *turgidum*) in New Zealand. The hybrid seeds were raised at Indore with the hope that it would provide a promising material for improvement of *Malvi* wheats. Growing of subsequent generations and single plant selections made in them did not give encouraging results as these selections carried lateness of Cambridge Rivet parent and hence were quite unsuitable for this tract.

It would be evident from these facts that in spite of the repeated attempts to bring single plant selections from wheat growing areas in Madhya Bharat and testing them at the Institute, no appreciable success was achieved. It was, therefore, thought desirable to tackle the problem of wheat improvement in Malwa from another aspect which consisted of : (1) Studying the genetic variability of the local material, (2) studying varietal differences between local and outside strains in terms of morphological development, and (3) to work out a more rational method of selection. The details of these studies are described in this article.

As a result of genetic studies, it was revealed that there was no genetic variability present in the local *Malvi* wheats and to make selection effective, genetic variability

had to be created by hybridisation with outside material. Hybridisation work was, therefore, started in 1944 between Malvi *durums* and *durum* strains from Bombay, Hyderabad and Madhya Pradesh. A large number of F_1s and F_2s were grown in the following years. In 1946, there was an unprecedented epidemic of rusts in India with the result that the entire crop of *durum* wheat including the hybrid material was destroyed and no seed was left for sowing in the following years.

Hybridisation, therefore, had to be restarted between local *durums* and *vulgare* strains, and rust resistant exotic types, namely, 'E. 144' 'E. 145,' 'Ex. 27,' 'Ex. 28,' 'Ex. 29,' etc., obtained from Powarkheda (M. P.) and Niphad (Bombay). Fifty progenies of the following F_2 hybrids were sent to Mahableshwar in 1950 for testing their seedling and adult resistance to races of black rust (*Puccinia graminis tritici*). Of these 50 progenies, 16 progenies had 59 resistant to moderately resistant plants which were later on transferred in 1951 to the All India Co-ordinated Wheat Rust Scheme stationed at Indore under the joint technical direction and guidance of the Head of Division of Botany, Indian Agricultural Research Institute, New Delhi, and the Director, Institute of Plant Industry, Indore. These plants are as under :

Species	Serial No.	Parentage	No. of progenies	No. of resistant and moderately resistant plants
T. vulgare	1	N.24 × E.144	3	17
	2	N.24 × E.145	5	9
	3	N.24 × E.117A	1	3
	4	Pissi 9 × Thatcher	1	..
	5	C 591 × Ex. 3	2	..
		Total	12	29
T. durum	6	EK. 69 × W_1-H_1	2	6
	7	EK. 69 × W_1-H_2	1	..
	8	EK. 69 × W_1-H_3	3	..
	9	EK. 69 × W_1-H_4	2	..
	10	EK. 69 × W_1-H_5	5	2
	11	EK. 69 × W_1-H_6	4	8
	12	EK. 69 × W_1-H_7	4	3
	13	EK. 69 × W_1-H_8	4	1
	14	EK. 69 × W_1-H_9	4	4
	15	EK. 69 × W_1-H_{10}	5	6
	16	EK. 69 × W_4-H_1	1	..
	17	EK. 69 × W_4-H_3	2	..
	18	EK. 69 × W_4-H_6	1	..
		Total	38	30
		GRAND TOTAL	50	59

BIOMETRICAL GENETICAL STUDIES

(a) Heritable variability

The unselected bulk which the cultivator grows year after year has a well adapted population consisting of a great range of types and store of variability.

The breeder has, therefore, first to ascertain the amount of genetic variability present in the material which he is going to handle. The success of evolving a new strain from such a population will depend upon the amount of genetic variability initially present in that material. Special statistical methods have been described by Panse [1940, a] to estimate this genetic variance.

When *Malvi* wheat failed to respond to selection it was thought desirable to find out first the amount of genetic variability present in it. Samples of local *durum* wheat from Rajgarh, Dewas, Indore, Dhar, Barwani, Ratlam, Jaora, Jhabua, Sitamau and Partabgarh States were, therefore, obtained and a study was undertaken by the author in 1941-42 and 1942-43 seasons. It was found [Simlote, 1949] that there was very little genetic variability present in samples except those from Jhabua and Barwani States. This small amount of genetic variability in them was due to the fact that the cultivator was making his own selection to maintain purity of seed and was using the same seed year after year for sowing. This repeated selection combined with the fact that wheat is a self-fertilized crop has resulted in the elimination of all variability.

TABLE IV

Genetic variance and the regression coefficients of samples from Barwani and Jhabua States

Samples	Tillers per plant		Ears per plant		No. of grains per ear		Weight of 100 grains (in grams)	
	bl	Gen. var.	bl	Gen. var.	bl	Gen. var.	bl	Gen. var.
Jhabua Kathia	+0·99	5·22	+1·00	3·92	..	..	+0·26	0·16
Barwani white	+0·75	1·24	+0·11	0·15	..	..	+0·34	0·11

Developmental studies, described later in this article, have shown that a high number of tillers and large ears are associated with higher yield of grain. Selection for higher number of tillers and large ears could be most effective in wheat from Jhabua which has shown the highest genetic variability in these two characters. Sample of wheat from Barwani State has shown 75 per cent of the variance as genetic for tiller number and about 34 per cent for weight of 100 seeds. Hence selection in this sample would be very successful. These samples from Jhabua and Barwani, therefore, offer the best scope for selection for higher yield out of so many tested.

The other samples do not possess genetic variability in other sub-characters of yield and hence are unsuitable for making further selections.

(*b*) *Genotypic value of yield from phenotypic observations of sub-characters of yield*

Yield in wheat depends upon the number of ears per plant, number of grains per ear and weight of single grain (generally taken as weight of 100 grains). Since yield and the sub-characters of yield are subject to non-heritable variation, selection made on the basis of such observable characters may not prove effective. Fisher's discriminant function [1936] shows the extent to which each character is genetically related to yield.

Such functions have been worked out by Simlote [1947] on samples collected from two different sources showing varying amount of variability. These sources are : (i) samples of *durum* wheats collected from Bengal, Madhya Pradesh, Hyderabad, Bombay and Madhya Bharat, and (ii) bulks of selected progenies from local *Malvi*.

Discriminant functions for each group were calculated according to Smith [1936] after transforming the data into logarithms ; these are given below :

(*a*) $Y=+2{\cdot}3440\ X_1-1{\cdot}8589\ X_2-{\cdot}7749\ X_3+{\cdot}7218\ X_4+{\cdot}2280X_5$

where Y=genetic yield of grain in log.

X_1=log. of mean number of tillers per plant

X_2=log of mean number of ears per plant

X_3=log of mean number of grains per ear

X_4=log of mean weight of 100 grains (gm).

X_5=log of mean weight of straw per plant (gm).

When tillers were omitted from the calculations, a new function was obtained which is given below :

(*b*) $Y=+{\cdot}6058X_2+{\cdot}0506X_3+1{\cdot}1201X_4-{\cdot}2253X_5$

In function (*a*), the coefficients for tiller number and weight of 100 grains are positive and high, and for straw weight positive and small. The coefficients for ear number and number of grains per ear are negative and high. In function (*b*), the coefficients for ear number, weight of 100 grains and number of grains per ear are all positive but the first two are high and the third very small. Coefficient for straw is negative and small. This means that in function (*a*), number of tillers, weight of straw and weight of 100 grains are positively correlated, and number of ears per plant and number of grains per ear are negatively correlated with the genetic yield of the samples. In function (*b*), number of ears per plant and grain weight were found to be positively correlated and straw weight was found to be negatively correlated with the genetic yield. Number of grains per ear though positively correlated on account of its small coefficient, would not affect the score of the variety obtained by substituting the mean values of characters X_1—X_5. The score thus obtained will represent the genetic yield of the variety.

Function for samples from (ii)

(c) $Y=+2{\cdot}2335X_1-2{\cdot}2658X_2+{\cdot}2639X_3+2{\cdot}0064X_4$

Straw weight was not recorded.

The coefficients for number of tillers and weight of 100 grains in function (c) are positive and high. Coefficient for number of ears is negative and high, and the coefficient for number of grains per ear is positive and small. In samples of low variability, therefore, selection should be based on number of tillers and weight of 100 grains which are very highly correlated with the genetic yield of the progeny bulks. Number of ears per plant was again found to be high and negatively correlated with the genetic yield. Number of grains per ear was found to be positively correlated, however, its coefficient being small, it could not influence the result in favour of high yield.

It can, therefore, be definitely concluded that for Indian *durum*, number of tillers and weight of 100 grains are the only characters which should be considered at the time of making selections for high yield of grain.

Genetic advance. The expectation of genetic advance through the use of discriminant function in samples collected from different provinces would be about 16·4 per cent when all the five characters are considered, but when tillers are omitted the expected advance would still be 5·2 per cent. This difference has brought out the importance of tillers in selection in *durum* wheats.

In samples of low variability, i.e., progeny bulks from local *Malvi*, the expected improvement over ordinary selection would be about 10 per cent.

Morphological development of local and outside varieties and comparison of other economic characters

As has been reported earlier, local bulks of wheat were found superior to imported 'ready made' strains as well as to new local selections. Since yield of grain in wheat depends upon several sub-characters, a comparative developmental study of these characters which make up the yield, would give us a clue as to the yielding capacity of different local and outside varieties in terms of morphological development. For this purpose, five varieties (two from the Institute and one from Bombay, Hyderabad and Madhya Pradesh) were selected for such a study. Fortnightly counts of tillers starting from 30 days after sowing and weekly counts of ears starting from the appearance of first ear, were taken on plants selected at random. After the harvest, number of grains per ear, weight of 100 grains and mean yield per plant were also recorded. The studies were carried out for two consecutive years (1941-42 and 1942-43) to get confirmatory results.

As a result of this study it was found that the Institute types were superior to the outside types in number of tillers and ears per plant, weight of 100 grains and yield of grain per plant, but were poorer in number of grains per ear. The local types were found well adapted to local environmental conditions, but the response to outside varieties varied in different seasons [Simlote, 1951].

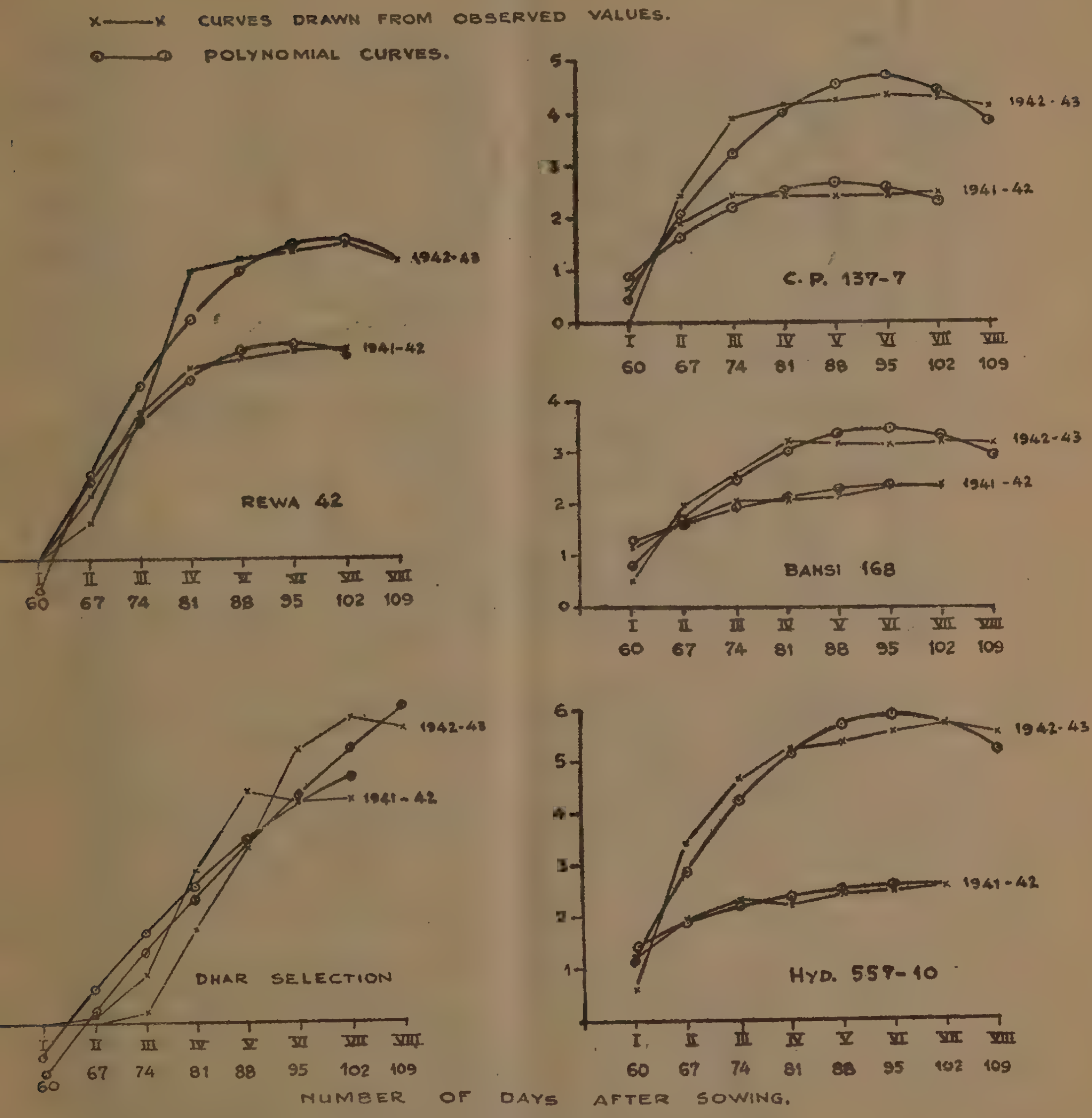

Fig. 1. Tiller frequencies of 1941-42 and 1942-43 seasons.

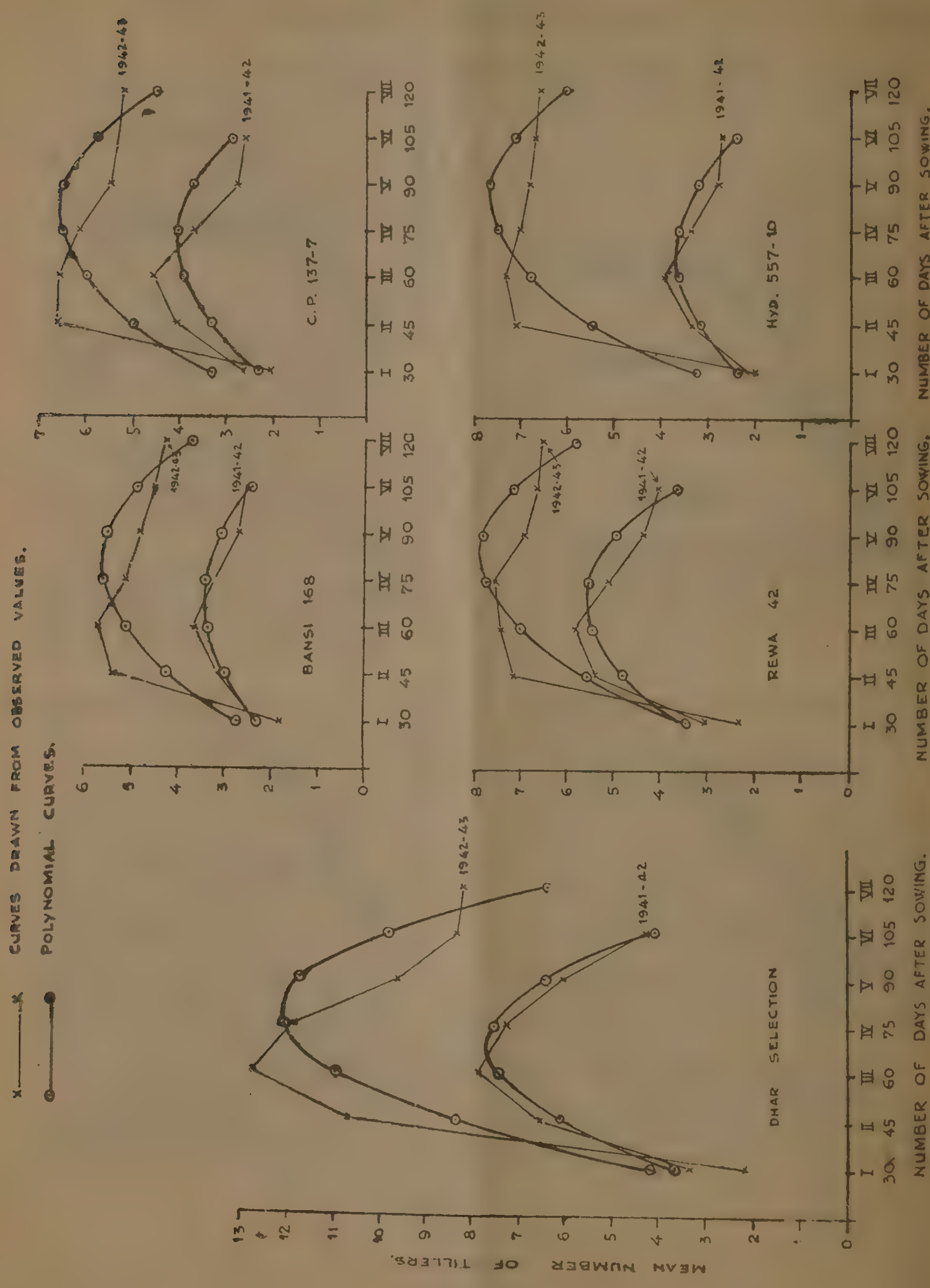

Fig. 2. Ear frequencies of 1941-42 and 1942-43 seasons.

TABLE V

Values for each character for two seasons

Variety	Source	Tillers per plant		Ears per plant		No. of grains per ear		Wt. of 100 grains (gm.)		Mean yield per plant (gm.)	
		1941-42	1942-43	1941-42	1942-43	1941-42	1942-43	1941-42	1942-43	1941-42	1942-43
Dhar selection	I.P.I.	4·39	8·23	4·34	5·65	15·9	13·1	5·18	4·92	14·8	18·6*
Rewa 42	I.P.I.	4·07	6·51	4·04	5·73	17·4	17·8	4·89	5·41	17·8	25·8
Hyd. 557-10	Hyderabad	2·72	6·61	2·62	5·51	19·8	26·2	4·32	4·59	10·5	26·6
137-7	Madhya Pradesh	2·70	5·26	2·48	4·17	22·9	23·6	3·87	4·75	11·1	22·5
Bansi 168	Bombay	2·50	4·28	2·38	3·13	22·7	27·0	4·39	4·46	12·1	16·1
S. E.		0·35	0·77	0·32	1·04	1·3	1·4	0·14	0·19	2·7	5·7
Significant difference		1·05	2·30	0·96	..	3·9	4·1	0·42	0·57	..	..
P		<·05	<·05	<·05	>·05	<·05	<·05	<·05	<·05	>·05	>·05

*Plots damaged by rats.

Values for all characters were higher in 1942-43 than in 1941-42, this was partly because the former season was better from an agriculturist point of view as there were light showers of rain in the month of December and January, secondly the experiment in 1942-43 was carried out on a richer soil and an additional watering was given one month after sowing.

The rate of tiller formation is mainly a varietal characteristic and is significantly different among the varieties. 'Dhar selection' gave the highest number and 'Bansi 168' the least; the remaining three in between the two. Second degree polynomial curves were fitted to counts of tillers of each variety to show the rate of tiller development graphically (Fig. 1). The average rate of tiller development was more rapid in 1942-43 than in 1941-42. The two curves of 'Dhar Selection' for 1941-42 and 1942-43 show a very rapid rate of development and also the fall after the maximum was reached. In the remaining varieties, the rate of tiller development and subsequent deaths were more gradual and formed flatter curves (Fig. 1).

The commencement of ear emergence synchronised with the period of maximum tillering, namely, sixty days after sowing. The Institute varieties were late by about a week or fortnight but produced more ears than others. As in tiller, the differences in ear formation were varietal and the number of ears was highest in 'Dhar selection' and least in 'Bansi 168'. Like tillers, the rate of ear development was studied graphically and was found to be different in different varieties (Fig. 2). The rate was highest in 'Dhar selection' and 'Rewa 42' and least in 'Bansi 168.'

With regard to the number of grains per ear, the Institute varieties had significantly lower number than the outside varieties but this was compensated by heavier seed weight of 100 grains, characteristic of the *Malvi durum* types.

There were no significant differences in the yield of grains per plant among the varieties in either season but the Institute varieties gave numerically higher yield than the other varieties.

These studies have shown that to evolve a high yielding variety for Malwa, selection should be done from the local material, which is not only well adapted to the local conditions but is superior to outside varieties in other characters, provided there is enough genetic variability present in the material. As has been stated earlier, the present local material has very little genetic variability. Genetic variability should, therefore, be created by hybridisation and then selection made from the hybrid material.

Effect of vernalization

Vernalization is a method of seed treatment which has in view the shortening of the period of growth and aims at providing the plant with necessary conditions for the completion of certain stages of development before the seeds are sown.

Since the developmental studies had shown that *Malvi* wheats were late in tiller and ear development by about a week or more, it was thought desirable to vernalize some of the local varieties to bring earliness in them by this method. For this purpose, one local *durum* and one local *vulgare* selections were treated as follows :

Sixty grams of each variety were weighed in an aluminium box and 20 c.c. of distilled water was added to each to make up the moisture content of the grains to

Table VI(*a*)

Results of the vernalization experiment conducted in 1945-46

Varieties	Treatments	Average numbers of tillers per plant — No. of days after sowing			Average numbers of ears per plant — No. of days after sowing			Yield of grain per plant (gm.)
		30	60	135	68	100	132	
Family 37 (*T. durum*)	11 days	1·99	8·03	5·12	0·45	5·15	4·16	6·02
	19 days	1·95	7·39	4·67	0·46	4·65	3·81	7·67
	27 days	2·03	7·24	4·71	0·37	5·02	4·01	7·84
	Control	1·95	7·16	4·87	0·46	4·97	3·92	7·78
Pissi 9 (*T. vulgare*)	11 days	1·92	7·23	4·61	0·80	4·81	4·20	7·84
	19 days	2·04	6·94	4·41	0·68	4·63	3·87	6·21
	27 days	1·81	7·17	4·81	0·65	4·99	4·28	6·71
	Control	1·72	6·44	4·47	0·60	4·57	3·85	7·92

50 per cent. taking for granted that dry grains normally contain about 13 per cent. moisture. In order to accelerate sprouting of seeds, 2 c.c. of water was added. These boxes were then kept in an almirah for about 24 hours after which many

seeds were found sprouted. After removing the unsprouted seeds, the boxes were kept in a frigidaire for different periods of 27 days, 19 days and 11 days, at 5° to 7°C. The treated seeds were then sown in five replicated randomized blocks at the Institute together with untreated seeds of each variety as a control. Fortnightly counts of tillers were taken after 30 days of sowing and continued till harvest; weekly counts of ears were started as soon as ears appeared and continued till maturity. After harvest, mean yield of grains per plant was also recorded. Table VI (*a* & *b*) gives the number of tillers, ears and mean yield per plant for 1945-46 season. The experiment was repeated in 1946-47 season, but on account of heavy rust infection the entire experiment was affected and no grains could be collected.

TABLE VI(*b*)

Results of the vernalization experiment conducted in 1945-46

		Average number of tillers per plant	Average number of ears per plant	Mean yield of grains (gm.) per plant
I. Varieties	Family 37	4·76	3·12	7·32
	Pissi 9	4·47	3·15	7·17
	S. E.	0·14	0·098	0·17
	P.	>·05	>·05	>·05
II. Treatments	11 days	4·82	3·26	7·27
	19 days	4·57	3·02	6·94
	27 days	4·63	3·22	6·93
	Control	4·44	3·06	7·84
	S. E.	0·16	0·14	0·71
	P.	>·05	>·05	>·05
III. Number of days after sowing		1·92(*a*)	0·56(*d*)	..
		7·20(*b*)	4·85(*e*)	..
		4·71(*c*)	4·01(*f*)	..
	S. E.	0·12	0·18	..
	Significant difference	0·34	0·47	..
	P.	<·05	<·05	..

(*a*) 30, (*b*) 60, (*c*) 135, (*d*) 68, (*e*) 100, (*f*) 132 days

It would be seen from Table VI(*b*), that no significant differences were noted among the treatments for any of the three characters recorded in either variety, but significant differences were obtained in tiller and ear number taken at different dates of observation, i.e., number of days after sowing.

In Family 37 there was a slight increase over control in mean number of tillers produced in the treated plots after 30 and 60 days of sowing, but the mean number of tillers survived at harvest was less than that in the control plots. Mean number of ears and yield of grains of the control plots were higher than that in the treated plots.

Pissi 9 responded slightly to the treatments. The mean number of tillers and ears was higher in the treated plots than in the control. There was no effect on the yield of grain per plant.

It was unfortunate that weight of 100 seeds was not taken.

Agronomical studies

Effect of sowing dates on the yield of wheat under barani *conditions*

In order to investigate the possibility of sowing wheat over a wide range of period instead of sowing the entire crop within a short span of time, experiments on different dates of sowing were started in 1944 by the author. Later on, it was observed that the crop could also be saved in bad years from damage by rust if the sowing could be delayed. Hence experiments were continued upto 1950 by the Agronomy section. The first two years were only exploratory and from 1947 regular experiments were carried out except in 1946 when all wheat experiments were destroyed by rusts.

In 1944, four dates of sowing were included at an interval of nine days starting from the 23rd October, 1944. The experiment was carried out on fields of low and high fertility. In 1945 the number of dates of sowing was increased to five to cover still wider range of period with the same interval beginning from the 17th October, 1945, and was carried on low and high fertility fields. Moisture percentage was also determined this year on samples of soil taken at random on the day of sowing from each plot and analysed statistically. From 1947 onwards, four dates of sowing at an interval of 15 days were included and the first sowing was done on 15th October, each year. In the first two years of experiment, three varieties of *T. durum*, viz. 'Ek. 69', 'Bansi 168' and 'Hyd. 557-10', were included but from 1948 only two varieties, viz. *Malvi* local and 'C 591' were tested except in 1947 when 'C 591' and 'N. 24' were included. Differences between the three *durum* types were significant on rich soil. 'Hyd. 557-10' responded well and gave significantly higher yield than 'Ek. 69', but on poor fields its behaviour was equal to that of 'Ek. 69'. 'Bansi 168' was more or less consistent in its yield. 'Ek. 69' did not respond to better class of soil. In later trials *Malvi* local gave significantly higher yield of grain than 'C 591'.

Significant differences in yields of grain were found due to different dates of sowing on fields of high fertility in the first two seasons. Higher yields were obtained

when sowings were finished by the end of October, but when continued for another week, the differences were not significant. The yields were, however, significantly lower when sowings were continued after 10th November. On fields of low fertility even the fourth sowings, 19th and 13th November, 1944 and 1945 respectively, had given higher yield than the first sowing probably on account of bad drainage whereby more moisture was retained as would be seen from the table of moisture percentages. Though the differences in moisture content of the soil of two fields were of the same magnitude, soil from poor field had higher moisture content and this may help us to explain for the higher yield of grain in the fourth sowings. Moisture percentages of the two fields did not differ widely but they were highest at first sowings, then gradually decreased as the sowing date advanced till they were significantly lowest on last sowings (Table VII).

As regards results from 1947 onwards, it would be seen from Table VII that differences in yields of grain of wheat were significant in three seasons out of four (1947-1950) and that these significant differences were mainly due to very low yields in the last sowing. Yields of grain from first and fourth sowings were invariably lower than those from second and third sowings, though yields of the fourth sowing only were significantly lower. Yield from the fourth sowing was consistently lower in spite of the fact that there were light showers in the last week of November in 1948 and 1949. Yield from the third sowing in 1950 was significantly lower than that from the first and second sowings as the season was dry and the moisture from surface receded rapidly.

It can, therefore, be concluded that sowing of wheat should be completed by 30th October every year but it could be extended for a week or so ; after that period if sowings are continued, the return may not be economical. It was also observed that besides moisture there was another factor which greatly helped in the establishment of plants after sowing because yields in the second and third sowings were invariably higher than those in the first sowings. Looking at the soil temperatures taken at the Institute observatory on uncropped area (no temperatures were recorded on cropped area) it was found that temperatures during the first sowings were always higher than during the subsequent two sowings. Temperatures during the fourth sowings were too low for effective germination and hence the yields were poor. It was, therefore, observed that temperature had, in addition to moisture, a great influence on the germination and establishment of plants. In order to get high yields, sowings should not be very much delayed beyond the first week of November, when moisture content of the soil goes down and the temperature also drops.

Effect of seedrate on the yield of wheat under barani *and irrigated conditions*

Barani *conditions.* A preliminary trial to find out an optimum seedrate per acre for *barani* conditions was carried out by the author in 1944 on high and low fertility fields with three seedrates, viz. 30 lb., 50 lb. and 70 lb. and three varieties, viz. 'Hyd. 557-10', 'Bansi 168' and 'Ek. 69'. Differences due to different seedrates were not significant on either fields, but differences among the varieties were

TABLE VII

Effect of sowing date on the yield of grain under barani *conditions*

Year		Dates					Sig. diff.	Varieties			Sig. diff.
		23 Oct.	1 Nov.	10 Nov.	19 Nov.						
								Hyd. 577-10	Bansi 168	Ek 69	
1944-45	Rich field	455 lb.	572 lb.	561 lb.	363 lb.		109	530 lb.	500 lb.	434 lb.	94 lb.
								Bansi 168	Ek. 69	Hyd. 557-10	
	Poor field	313 lb.	321 lb.	353 lb.	380 lb.		..	377 lb.	369 lb.	279 lb.	96 lb.
	Temperature	72°-73°F	71°-72°F	69°-70°F	65°-68°F						
1945-46		17 Oct.	26 Oct.	4 Nov.	13 Nov.	22 Nov.		Hyd. 557-10	Bansi 168	Ek. 69	
	Rich field	538 lb.	584 lb.	569 lb.	469 lb.	334 lb.	47	528 lb.	505 lb.	464 lb.	61 lb.
	Poor field	416 lb.	580 lb.	460 lb.	455 lb.	303 lb.	75	450 lb.	481 lb.	398 lb.	
	Temperature	73°-78°F	72°-76°F	69°-71°F	67°-70°F	65°-66°F					
	Moisture percentage—										
	Rich field	20·9	20·9	20·3	20·0	19·3	0·36				
	Poor field	21·3	20·6	20·4	20·2	19·7	0·44				
1946-47		Crop of wheat failed due to rust epidemic									
1947-48		15 Oct.	30 Oct.	15 Nov.	30 Nov.			C. 591	N. 24		
	Yield	209 lb.	343 lb.	357 lb.	223 lb.			314 lb.	252 lb.		62 lb.
	Temperature	74°-76°F	70°-73°F	67°-68°F	65°-66°F						
								Malvi 949	C. 591 1043		
1948-49	Yield	1,064 lb.	1,181 lb.	994 lb.	747 lb.		157 lb.				
	Temperature	80°-82°F	77°-81°F	70°-75°F	67°-69°F						
1949-50	Yield	651 lb.	733 lb.	700 lb.	387 lb.		160 lb.	666 lb.	570 lb.		68 lb.
	Temperature	78°-81°F	73°-79°F	68°-75°F	69°-71°F						
1950-51	Yield	391 lb.	412 lb.	242 lb.	59 lb.		95 lb.	316 lb.	237 lb.		67 lb.
	Temperature	76°-78°F	71°-75°F	66°-71°F	64°-66°F						

In all cases P = ·05

TABLE VIII-A

Effects of spacings, seedrates and manures on the yield of Malvi 'Ekdania' *wheat under un-irrigated conditions*

Year	Soil fertility level	Seedrates per acre														
		30 lb.	50 lb.	70 lb.			S. E.	Sig. diff.								
		Lb.	Lb.	Lb.												
1944-45	Medium	497	514	489			17·4									
	Poor	345	349	358			13·1									
	Soil fertility	40 lb.	60 lb.	80 lb.	100 lb.	120 lb.	S. E.	Sig. diff.	9 in.	14 in.	S. E.	Sig. diff.	Treated	Un-treated	S. E.	Sig. diff.
		Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
1947-48[1]	Poor					Experiment failed because of defective germination.										
1948-49[2]	Medium	916	929	734	696	649	48·5	141	775	792	30·7		790	770	46·0	
1949-50[3]	Medium	810	809	712	805	736	28·8	84	758	795	18·2		784	761	27·4	
1950-51	Poor	475	416	428	472	466	25·7		478	429	16·3					
	Mean	734	718	628	658	617										

P = ·05 in all cases

[1] Experiment consisted of four replicates, of which two were manured with groundnut cake at 25 lb. N per acre.

[2] Experiment consisted of six replicates, of which two were manured a fortnight before sowing and two at the time of sowing with groundnut cake at 20 lb. N per acre.

[3] Same as in 1948-49.

found significant as has been stated before while discussing the effect of sowing dates on the yield of wheat under *barani* conditions.

Such an experiment was restarted in 1947 with five seedrates, viz. 40 lb., 60 lb., 80 lb., 100 lb. and 120 lb. per acre, and two spacings, viz. 6 in. and 12 in. in 1947 and 9 in. and 14 in. in 1948, 1949 and 1950 seasons. The experiment was repeated for four consecutive years both under *barani* and irrigated conditions. In 1947 season, out of four replicates, two were manured with groundnut cake at 25 lb. N per acre and two were left unmanured. In 1948 and 1949 seasons, out of the six replicates, two were manured a fortnight before sowing and two at the time of sowing with groundnut cake at 20 lb. N per acre. In 1950 season, no manurial treatments were given.

In 1947, the whole experiment was abandoned as the germination was not satisfactory on account of the lack of sufficient moisture at the time of sowing during the middle of October.

Differences in yields of grain due to seedrates were significant in two out of three seasons. In 1948 season, yields from plots which were sown at the rates of 40 lb. and 60 lb. per acre were significantly higher than those sown with higher seedrates. In 1949 season, however, the yields from plots with the above two seedrates were significantly higher than those obtained from plots sown with 80 lb. per acre. Differences in yields of grain among the plots having the remaining seedrates were small and not significant (Table VIII-A). Differences in yields of grain due to spacings were not significant in any of the three seasons.

The average yield of grain obtained from manured and unmanured plots did not differ significantly in 1948 and 1949 seasons and the magnitude of differences between the average yields of the treatments in two seasons was of the same order (Table VIII-A). The interaction between seedrates, manured and unmanured plots and spacings, and manured and unmanured plots were also not statistically significant, indicating thereby that variation between plots within blocks due to manurial treatments was more or less of the same magnitude and, therefore, did not upset the results.

The above results, therefore, indicate that a seedrate of 40 lb. per acre appears to be advantageous under *barani* conditions in Malwa.

Irrigated conditions. In 1947, 1948 and 1949 seasons, three replicates out of six were manured with groundnut cake at 40 lb. N per acre, but in1950, out of six replicates two were manured with ammonium sulphate at 40 lb. N per acre, two with a mixture of ammonium sulphate and superphosphate at 40 lb. N and 40 lb. P_2O_5 per acre respectively, while the remaining two replicates were left untreated as control. Normally, two irrigations were given in each year, one at the time of earing and the other at the milky stage of the grains.

The yield of grain obtained from plots sown with five different seedrates included in the study did not differ significantly in all the four seasons, except in 1947 when plots sown with a seedrate of 40 lb. per acre gave significantly

lower yield than those obtained from plots sown with the seedrates of 80 lb., 100 lb. and 120 lb. per acre (Table VIII-B). Differences in yield of grain due to spacings were not significant in any one season under these conditions as well.

Application of nitrogen gave significantly higher yield of grain than those obtained from untreated plots in 1948 and 1949 seasons. In 1950 season, however, the yields from plots treated with a mixture of nitrogen and phosphoric acid was significantly higher than those from unmanured plots. Interaction between seedrates and manures, and spacings and manures were not significant in any one season. This means that variation between plots within blocks due to manures was of the same order.

On the basis of the above results, however, a seedrate of 120 lb. appears to be profitable under irrigated conditions, as it gave an average net grain of 57 lb. per acre over the seedrate of 80 lb. which is normally adopted by the cultivators in Malwa.

Effect of compost and fertilizers on the yield of wheat

Although wheat under *barani* condition is rarely manured in Malwa, preliminary experiment was carried out in 1934 to test the application of farm compost and municipal compost. Since the rain-watered compost is ready at the end of rainy season, the test included its application as soon as it was ready and to compare its application with pre-rain application. The experiment was carried out on two fields of medium fertility, one with defective drainage and the other with good drainage, to see their effects on the improvement of soil texture as well. Composts were applied at the rate of 20 cartloads per acre equivalent to 73 lbs. N per acre, as previous experience had shown that no significant increase in the yield of wheat was obtained by a rate lower than 20 cartloads per acre of any compost.

The results indicated that significant increase in the yield of wheat was obtained from the field with defective drainage, in the case of post-rain application of farm compost and pre and post-rain application of municipal compost. This higher yield was more due to better retention of moisture after the cessation of rains by the field than due to nutrients. The application of compost also improved the tilth which helped in the development of the plant. Drainage is very important for *kharif* crops but for *rabi* crops a poorly drained soil may be preferred as it can be improved by the application of compost thereby getting higher yield. On well drained field with better texture, increase in yield by compost would not be so pronounced.

Table IX gives the yield of wheat under different treatments.

As regards other manures and fertilizers, experiments were laid out for the first time at the Institute in 1944 by the author to study the response of *durum* wheats under *barani* conditions. In that year, three levels of N, viz. 20, 40 and 60 lb. per acre in the form of ammonium sulphate and two levels of P_2O_5, viz. 20 and 40 lb. per acre in the form of superphosphate were adopted. The fertilizers were drilled in the soil by an ordinary seed drill before the seeds were sown. Variety 'Ek. 69' was tested. Statistical analysis of the grain yield data revealed that there was a

Table VIII-B

Effect of spacing, seedrates and manures on the yield of 'C-591' wheat under irrigated conditions

Year	Seedrates per acre							Spacing				Manures				
	40 lb.	60 lb.	80 lb.	100 lb.	120 lb.	S. E.	Sig. diff.	6 in.	12 in.	S. E.	Sig. diff.	N	N+P	Un-manured	S. E.	Sig. diff.
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
*1947-48[1]	614	652	740	738	743	37·4	106	703	692	23·6		780		664	23·6	
								9 in.	14 in.							
1948-49[2]	1,862	1,839	1,858	1,845	1,900	25·1		1,809	1,913	50·1		1,986		1,730	50·1	142
1949-50[3]	1,441	1,502	1,344	1,426	1,617	94·9		1,471	1,461	60·0		1,609		1,323	60·0	170
1950-51[4]	1,230	1,234	1,354	1,270	1,262	67·5		1,225	1,316	42·7		1,248	1,463	1,099	94·00	27
Mean	1,287	1,307	1,324	1,320	1,381											

$P = \cdot 05$ in all cases.

[1] Experiment consisted of six replicates, of which three were manured with groundnut cake at 40 lb. N per acre. Two irrigations were given.
[2] Same as in 1947-48. Two irrigations given.
[3] Same as in 1947-48. Three irrigations given.
[4] Out of six replicates, two were manured with ammonium sulphate at 40 lb. N per acre, two with a mixture of ammonium sulphate and superphosphate at 40 lb. N and 40 lb. P_2O_5 per acre respectively and two were left unmanured. Two irrigations were given.

Table IX

Yield of wheat under different drainage conditions

Time of manuring	Field with defective drainage			Field well drained			Significant difference	Analysis of compost		
	Municipal compost	Farm compost	No manure	Municipal compost	Farm compost	No manure		Type	N	P_2O_5
Before rains	728 lb.	623 lb.	589 lb.	430 lb.	422 lb.	404 lb.	61 lb.	Municipal compost	0·738 per cent	1·35 per cent
After rains	838 lb.	805 lb.	603 lb.	458 lb.	471 lb.	446 lb.	127 lb.	Farm compost	0·800 per cent	1·42 per cent

definite response to fertilizers under *barani* conditions. There was a better response to mixture of ammonium sulphate and superphosphate than to either of them alone. A mixture of 40 lb. N and 40 lb. P_2O_5 gave twice as much yield as the control. A shower of 1·42 in. on the fourth day of drilling the fertilizer helped the plants to take up N and P_2O_5 from the soil in large quantities (Table X).

In 1945 groundnut cake was included to supply both N and P_2O_5 in addition to ammonium sulphate and superphosphate. Three levels of N, viz. 20, 40 and 60 lb. per acre in the form of ammonium sulphate and groundnut cake and three levels of P_2O_5, viz. 20, 40 and 60 lb. per acre in the form of superphosphate and groundnut cake were adopted. As groundnut cake contains only one per cent P_2O_5, the requisite quantity of P_2O_5 was made up by the addition of superphosphate. N and P_2O_5 were mixed up in the proportion of 1 : 1. The drilling of manure was done as in last year and again 'Ek. 69' was used. Statistical analysis of the data confirmed the last year's findings that there was a definite response to fertilizers under *barani* conditions. In spite of the fact that the weather was dry after sowing, the manured plots gave, in general, significantly higher yield of grain than the control. There were, however, no significant differences among the various manurial treatments given either in pure or mixed forms.

It will thus be seen that application of manures and fertilizers, whether in pure or mixed form, has increased the yield of grain in both the seasons, but the effects were more pronounced in 1944, when more moisture was made available to the crop by a shower of 1·42 in. after drilling, than in 1945 when the weather was dry throughout the growing period.

In order to obtain information regarding the response to manures of other *rabi* crops, viz. gram and linseed, the experiment was re-planned in 1946 by the then Deputy Director for Research, to economise labour and to facilitate agricultural operations by combining the trial of all the three crops in one trial. The trial was carried out on two fields differing in fertility. The manurial treatments consisted of a combination of 20 and 40 lb. N per acre in the form of groundnut cake with 20 and 40 lb. of P_2O_5 as superphosphate. Manures were drilled before sowing. 'Ek. 69' and 'C 591' were tested in low and high fertility plots respectively.

The experiment in 1946 was badly damaged by rust epidemic in both the fields and 'Ek. 69' suffered the most. Yields were very poor but the treatment differences were significant in both the fields. Mixtures gave significantly higher yield of grain on field of high fertility but not on poor field.

In 1947 the germination in both the fields was very defective due to lack of moisture at the time of sowing and as there were no winter showers thereafter the experiment had to be abandoned.

In 1948 about 2·43 in. of rain fell after about a fortnight of sowing and wheat showed a good response to manuring in both the fields. Higher doses of mixture of N and P_2O_5 gave significantly higher yield than control on both the fields. Effects produced by the two fertilizers applied singly were very small and did not differ significantly from those in control.

TABLE X

Yield of wheat under barani *conditions due to different manurial treatments*

(pounds per acre)

Treatments	1944 Ek. 69	1945 Ek. 69	1946-47 C 591	1946-47 *Malvi*	1948-49 C 591	1948-49 *Malvi*	1949-50 C 591	1949-50 *Malvi*	1950-51 C 591	1950-51 *Malvi*
			Rich	Poor	Rich	Poor	Rich	Poor	Rich	Poor
20 lb. N (Ammonium sulphate)	584	677	..	..	..	..	..	..	556	396
40 lb. N Do.	581	645	..	..	..	..	..	..	..	..
60 lb. N Do.	625	700	..	..	..	..	..	..	..	..
20 lb. Groundnut cake	..	591	133	31	812	428	857	550	..	..
40 lb. Do.	..	658	139	27	887	524	847	570	..	..
60 lb. Do.	..	694	..	..	..	..	..	..	..	..
20 lb. P_2O_5, Superphosphate	528	..	125	32	821	482	850	535	485	417
40 lb. P_2O_5 Do.	509	..	133	48	928	551	856	554	..	..
Ammonium sulphate and Superphosphate										
20 lb. N+20 lb. P_2O_5	719	636	..	..	..	..	..	..	544	408
40 lb. N+20 lb. P_2O_5	819	..	..	..	..	..	..	..	..	..
60 lb. N+20 lb. P_2O_5	837	681	..	..	..	..	..	..	..	..
20 lb. N+40 lb. P_2O_5	766	..	..	..	..	..	..	..	..	..
40 lb. N+40 lb. P_2O_5	916	681	..	..	..	..	..	..	..	..
60 lb. N+40 lb. P_2O_5	884	..	..	..	..	..	..	..	..	..
60 lb. N+60 lb. P_2O_5	..	694	..	..	..	..	..	..	..	..
20 lb. N+20 lb. P_2O_5 G. N. cake superphosphate.	..	617	137	50	926	604	895	552	..	..
40 lb. N+20 lb. P_2O_5	..	..	154	30	1053	573	902	523	..	..
20 lb. N+40 lb. P_2O_5	..	..	166	46	993	592	869	533	..	..
40 lb. N+40 lb. P_2O_5	..	646	150	33	1119	637	923	512	..	..
60 lb. N+60 lb. P_2O_5	..	650	..	..	..	..	..	..	..	..
Control	465	548	112	21	788	428	691	445	450	316
Significant difference	65	79	30	18	164	102	150	..	84	49
S. E. per cent	3·4	4·5	10·6	6·4	6·2	6·6	4·3	5·6	5·5	3·5

In 1949 no significant differences in yield of wheat were produced by the application of fertilizers to both the fields and the yields from treated plots were higher than that from control.

In 1950 groundnut cake was replaced by ammonium sulphate, then 20 lb. N, 20 lb. P_2O_5, and a combination of 20 lb. N plus 20 lb. P_2O_5 were tried. On both the fields fertilizers produced significantly higher yields than the control, except on rich soil where 20 lb. of P_2O_5 was not significantly different from the control (Table X).

It would, therefore, be concluded from these trials that wheat did respond to manuring even under *barani* conditions. The effects of a mixture of these fertilizers were more pronounced if a shower followed their drilling. In the absence of a shower (Table XI) pure plots of N and P_2O_5 gave higher yield. Groundnut cake can be preferred to ammonium sulphate as it not only adds nitrogen and phosphoric acid but also organic matter to the soil. It is also cheaper than ammonium sulphate. The optimum dose would depend on the cost of fertilizers and manures but 20 lb. of N in the form of groundnut cake plus 20 lb. of P_2O_5 in the form of superphosphate appeared to be the best combination under the conditions in Malwa.

Effect of green manuring on the yield of wheat under barani *conditions*

The practice of green manuring fields where wheat is to be sown in the ensuing season, is a very old one and forms part of the cultivation programme on well established farms. In Malwa the average annual rainfall is about 36 in. and the months of heavy precipitation are July and August. Quite often heavy showers are received in September also, as such it is quite common in Malwa to green manure the fields. The cultivators grow sann (*Crotolaria juncia*) in the *kharif* season and when the crop is about two months old, it is ploughed into the field. Experiments, therefore, were started at the Institute in 1932 season with a view to find out

(i) the best leguminous crop to be ploughed in,
(ii) the stage at which the crop should be ploughed, and
(iii) the method of manuring the field.

These experiments were carried out from 1932 to 1935 and again in 1943 and 1944 and re-started in 1948. The results are given in Table XII.

(*a*) *Best leguminous crop as green manure.* In 1932 four leguminous crops, viz. black gram (*Phaseolus mungo* var. *radiatus*), cowpea (*Vigna catiang*), sann hemp (*Crotolaria juncia*) and soybean (*Glycine hispida*) were tried for the first time at the Institute for green manuring. All crops were sown on the 27th June, 1932. The seed-rates for different crops were different as they were adjusted to 40 lb. of sann per acre to give equal number of seeds per plot. They were black gram 29 lb. per acre, cowpea 54 lb. per acre and soybean 34 lb. per acre.

These crops were either cut and removed from the field or buried *in situ* whenever they came to flowering. The amount of total green matter produced by each crop is given in Table XII. After green manuring I. P. 4 wheat was grown.

TABLE XI

Weekly rainfall in inches from 15th September to 30th November

Year	September			October					November				
	III week	IV week	Total for the month	I week	II week	III week	IV week	Total for the month	I week	II week	III week	IV week	Total for the month
1944	4·57	0·27	5·56	2·79	0·31	..	2·07	5·17	..	..	..	..	..
1945	3·21	5·72	16·01	0·10	0·23	..	..	0·33	..	..	..	..	..
1946	0·16	0·47	2·88	0·84	0·72	..	..	1·56	1·31	3·56	1·32	1·34	7·53
1947	0·05	2·79	11·66	1·62	..	..	..	1·62	..	..	..	..	..
1948	0·49	0·32	7·20	0·44	0·33	..	..	0·77	0·97	..	0·20	1·26	2·43
1949	5·15	6·73	15·30	0·12	1·98	..	..	2·10	..	..	..	0·13	0·13
1950	8·69	0·23	16·09	..	0·14	..	..	0·14	..	..	..	..	..

TABLE XII

Effect of green manuring on the yield of wheat
(pounds per acre)

Year		Fallow	Green manure cut and removed				Green manure cut and ploughed in				Significant difference	Standard error (pre cent)
			Black gram	Cowpea	Sann	Soybean	Black gram	Cowpea	Sann	Soybean		
1932	Yield of wheat	475	635	597	577	472	604	479	558	554	103	6·7
	Green matter (lb. per acre)	..	6,424	5,818	8,288	4,894	7,045	5,850	7,000	5,484	1,685	..

Year	Fallow	Sann cut and removed at flowering stage (12 weeks after sowing)	Sann ploughed in at			Significant difference	Standard error (pre cent)
			Seedling stage (4 weeks)	Growing stage (8 weeks)	Flowering stage (12 weeks)		
1933	740	564	909	587	571	231	

TABLE XII—(*contd.*)

Effect of green manuring on the yield of wheat
(in pounds per acre)

Year	Fallow		Sann cut and removed				Sann ploughed in									
			Flowering stage (10 weeks)		Growing stage (6 weeks)		Flowering stage (10 weeks)		Growing stage (6 weeks)							
1934	933		997		978		1,004		1,068							
	Green manure cut and removed						Green manure ploughed in						Green manure cut and spread			
1935	6 weeks after sowing		8 weeks after sowing		11 weeks after sowing		6 weeks after sowing		8 weeks after sowing		11 weeks after sowing		6 weeks after sowing		8 weeks after sowing	
	Sann:	Cow-pea	Sann:	Cow-pea	Sann:	Cow-pea	Sann:	Cow-pea	Sann:	Cowpea	Sann:	Cowpea	Sann:	Cowpea	Sann:	Cowpea
Good field	252	388	400	440	368	424	208	420	284	452	424	384	340	280	240	356
Poor field	148	280	168	256	140	612	200	668	284	480	180	468	156	316	196	344
	Fallow		Sann buried in August by ploughing		Sann buried after flowering stage in September.		Sann buried in previously opened furrows		Sann cut and removed		Significant difference					
1943	481		454		430		431		395		..					
	Fallow		Sann cut and ploughed in by usual method		Sann cut and ploughed in previously opened furrows		Sig. diff.									
1944	700		720		667		..									

TABLE XII—(*contd.*)

Effect of green manuring on the yield of wheat
(in pounds per acre)

Year	No green manure	Green manure composted and added	Green manure buried by ploughing	Green manure buried in previously opened furrows	Significant difference	0 lb. P_2O_5	30 lbs. P_2O_5	Significant difference
1948	441	453	508	431	..	435	482	..
	No manuring	Green manure ploughed in before 15th August		..	Sig. diff.			
1949	403	403		..	..			
	Fallow	Green manure buried end of August	Mung as catch crop	*Urid* as catch crop	Sig. diff.	0 lb. P_2O_5	40 lbs. P_2O_5	Sig. diff.
1950	405	349	404	355	54	378	378	..

It was found that plots from which green matter of black gram was either cut and removed or buried gave highest yield of wheat and this was significantly superior to yield from plots where cowpea green matter was buried and soybean grown and cut. Differences in yields from other treatment plots were very small and did not differ significantly from yields of wheat from fallow plots. Though the yield of grain from sann plot was not significantly different in comparison with those from fallow plots, the amount of green matter produced was, however, the highest followed by black gram, cowpea and soybean. All leguminous crops, except sann, were badly attacked by insects and their leaves were all eaten up. Hence their green matter was considered to be unsuitable for burying in the fields.

In 1935 sann hemp was tried with cowpea alone under different methods of green manuring. The two crops were cut at different stages of their growth. The experiment was carried out on two fields, one with free drainage and the other with defective drainage (Table XII).

Green manuring with cowpea has given higher yield of grain than sann manuring on both the fields. The effect of green manuring with sann was more pronounced on well drained fields than on field with defective drainage. The depressed yield from poor field where sann was ploughed in, even when the moisture supply was sufficient, seemed to be due to unfavourable physical condition of the soil preventing aerobic decomposition of the dry matter. In 1951 *mung* and *urid* were introduced in the trial along with sann and were taken as catch crops. They were even manured with 40 lb. P_2O_5. Though the yield of wheat from the plot green manured with sann was significantly lower than those from fallow and *mung* plot, and almost equal to that from *urid* plot, it indicated that the cultivator can get more cash return per acre from his field by growing legumes like *mung* and *urid* in the *kharif* season and sowing wheat after them, than by growing sann and ploughing it in. This line of work should be continued.

(*b*) *At which stage should the crop be ploughed in.* Sann was ploughed in at seedling stage, growing stage (eight weeks old) and flowering stage, in 1933, 1934 and 1935 respectively. Cowpea and sann were buried after six, eight and eleven weeks of sowing. No conclusive results were obtained but the results gave an indication that better results could be obtained if the crop was ploughed in either at the growing (before 15th August) or flowering stage provided there was a shower following it to accelerate the decomposition of organic matter ; otherwise there would be competition between the undecomposed stalks and wheat plants for moisture, thereby lowering the yield of wheat.

(*c*) *Method of green manuring.* Generally the crop is ploughed *in situ* after the plants are pressed flat on the ground but various other methods were also tried, viz., (i) cutting and removing, (ii) cutting and spreading in the same field, (iii) cutting and burying in previously opened furrows, and (iv) composting green matter and adding.

The complete decomposition of a green manure crop under *barani* conditions would obviously depend upon the amount of moisture left in the soil or received

as rains after the crop is ploughed in. Since crop of sann gets ready for ploughing after heavy rainfall period is over, it has been often found that large quantities of organic matter remain undecomposed, thereby affecting the succeeding crop of wheat. Experiments were started to devise means whereby rain-water could be stored in furrow, previously opened by an iron plough, before the crop is ploughed in.

No definite results were obtained due to different methods of disposal of crop and also when the crop was manured with phosphate manures. But it has been observed by looking at the data of past experiments, that green manuring by any method did not give higher yield than no manuring in the first year of application; its residual effects on wheat have not been tested. It was also found that green manuring on poorly drained fields may depress the yield even if the moisture be sufficient. This may be due, as mentioned above, to unfavourable physical conditions of the soil preventing aerobic decomposition.

Effect of tillage and interculture on yield

In the *rabi* season of 1932-33 the yield of local *durum* wheat was determined when it was grown with and without interculture, after different types of preparatory cultivation at the end of the rains. The experiment included a comparison of three types of preparatory cultivation: (*a*) cross ploughing 3-4 in. deep with a *desi* plough, (*b*) ploughing 6-7 in. deep by Ransome's C. T. 2 inversion plough, and (*c*) no cultivation. This was followed by two *bakharings*. The effects of interculture and no interculture were also included in the test, which were noted after 38 days of sowing. Moisture content of the soil in the second four-inch layer (4-8 in.) was also determined simultaneously.

Interculture had no influence on the yield of wheat. In Malwa, during *rabi* season, usually the cultivator does not carry out any intercultivation. These results have merely corroborated this fact. The moisture content of the second four-inch layer was not affected by any of these treatments. No significant differences were found for either yield of grain or *bhusa* with any of the treatments.

Only one year's data are available which are given in Table XIV. The yield of wheat under *barani* conditions did not increase by any type of tillage carried out

TABLE XIII

Influence of tillage on moisture retention and wheat yields

	Interculture			Interculture			
—	Cross ploughing 3-4 in. deep by a *desi* plough	No cultivation	Ploughing by C.T. 2 plough 6-7 in. deep	Cross ploughing 3-4 in. deep by a *desi* plough	No interculture	Ploughing by C.T. 2 plough 6-7 in. deep	Significant difference
Total moisture percentage (4-8 in.).	16·5	16·3	16·4	15·5	16·9	17·6	..
Wheat grain (lb. per acre).	377	394	369	394	353	418	..
Bhusa (lb. per acre)	914	1,068	898	947	934	883	

during *kharif* season nor by interculturing the plots; all the same, neglect of such operations during *kharif* season resulted in the establishment of pernicious weeds like *kans* (*Saccharum spontaneum*).

Pests and diseases

Pests

No serious damage has been observed on wheat by any insect pest. The only pest is the pink stem-borer (*Sesamia inferens* W.). Sporadic attacks by the borer are observed in wheat fields. In dry season the pest gets serious and causes wilting of plants by boring into the stem. The ears turn yellow and droop down. The attack continues upto the harvest time. As the caterpillar feeds on some other graminaceous weeds, it can pass from one season to next very easily. No remedial measures have been evolved except to pick up the plants and burn them.

Diseases

(i) Loose smut, caused by *Ustilago tritici*, is fairly common in the tract. The disease manifests itself only when the plants are in ears. The diseased ears emerge out of the boot leaf a little earlier than the healthy one, and a black powdery mass of spores takes the place of flowers. The only practical remedy is to uproot the plants and burn them, but growing of immune or resistant varieties offers the best method of getting rid of the disease [Pal and Mundkur, 1941].

(ii) Rust is the most important disease of wheat. Unfortunately all the three rusts, viz. black or stem rust caused by *Puccinia graminis tritici*, brown rust caused by *Puccinia triticina* and yellow rust caused by *Puccinia glumarum* are found in India. Black and brown rusts are found in Malwa also, but the most destructive rust is the black rust. Of the eleven races of black rust found in India, races 15, 40, 42 and 75 are common in this tract. It occurs every year in Malwa but generally later in the season thereby causing very little or no damage to the wheat crop grown under *barani* conditions. The infection in Malwa comes from the infected plants in North India. In 1946 the rust appeared very early, sometime in the first week of December and destroyed the entire *Malvi* wheat which was still in the booting stage. *Vulgare* wheats like 'C. 591' and 'I. P. 52' were comparatively less damaged on account of their quick growing habit and the character of having a few leaves on the plants.

The breeding of resistant varieties appears to be the only suitable practical method by which rust incidence can be controlled. Resistance to black rust is governed by genetic factors which control a group of physiological races of this parasite. After the epidemic of 1946, crosses were made by the author between local *vulgare* and *durum* types, and exotic types with a view to evolve rust-resistant types for Malwa. As has been mentioned under plant breeding studies, a few F_2 hybrid families were sent to Mahableshwar for testing their rust resistance. As a result of this, a few plants were found resistant to black rust and these have been transferred to a scheme, which is in operation at this Institute since 1951, for breeding rust-resistant varieties in Malwa.

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STUDIES ON THE DISEASES OF SUGARCANE IN INDIA

IV. RELATIVE RESISTANCE OF SUGARCANE VARIETIES TO RED ROT

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As early as 1918 Butler wrote: "In India, red rot is in many places the greatest obstacle to successful cane cultivation. In Madras, Bombay and Bihar, the area under thick cane has, in certain districts, periodically shrunk as a result of an accumulation of this disease, to expand again only when the diseased cane has been replaced from outside".

During the 1938-39 season, as reported by Chona [1941], a red rot epidemic of unprecedented severity occurred in sugarcane crop of northern India, particularly in U. P. and Bihar, the main cane tract of the country, resulting in the widespread failure of the most predominant commercial variety, Co. 213. Thousands of cane fields were completely devastated and most of the sugar mills in the badly affected areas of eastern U. P., crushed only one-third of their normal crush of cane that season owing to poor supplies. The position during 1939-40 was only slightly better. The epidemic has driven Co. 213 completely out of cultivation from the tract where this cane variety had flourished and faithfully served the sugar industry for nearly a decade. The local Departments of Agriculture and Cane Development, and the Sugar Factories had to face the collosal task of replacing Co. 213 with some other suitable variety and arranging for the supply and distribution of thousands of maunds of seed cane material to keep up the sugarcane acreage in the tract. Co. 331 and Co. 299 were chiefly pushed up to replace Co. 213. But within two or three years of large-scale cultivation, these varieties became heavily infested with red rot and had to be abandoned by the cultivators. The Cane Development Department and the Department of Agriculture, U. P. were faced once again, within such a short period, with the problem of replacing these varieties.

During 1946-47 the red rot epidemic flared up again in U. P. chiefly affecting Co. 312 and an indigenous cane variety, locally known as *Mamchuah*. The epidemic this time was not confined to eastern U. P. but had spread even in central and western U. P., where Co. 312 is the chief commercial cane variety. It has now started spreading in the neighbouring cane area of East Punjab where Co. 312 is grown extensively.

Changing over to cane varieties other than Co. 213 or Co. 312 had certainly given great relief in the U. P. and Bihar epidemic tracts but unless a variety possesses sufficient degree of resistance to red rot, the beneficial effects will only be temporary as has been clearly seen in the case of Co. 299 and Co. 331. It is of utmost importance,

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114 during 1943-44, 97 during 1944-45, 22 during 1945-46, 79 during 1946-47, 94 during 1947-48 and 104 during 1948-49 were tested for their resistance to red rot. From 1945 onwards parent cane varieties, *Spontaneums*, *Sclerostachya*, etc. considered important for sugarcane breeding work, were also included in these tests. During the first five seasons of these tests, *C. falcatum* (isolate *Poovan*), the Coimbatore strain, isolate *Desi Ponda* from Shahabad Markanda (Ambala) and isolate No. 3 from *Shahabad Ponda*, Karnal, were used as inoculum, while during 1941-46 the inoculum consisted of the light type isolate 78, predominant in the U. P. and Bihar epidemic tracts during 1938-40, which was found to be much more virulent than the isolate *Poovan* and isolate No. 3. By 1946, the virulence of isolate 78 seemed to be falling off and it was replaced by isolate 244 for the 1947-48 and 1948-49 seasons' tests. Isolate 244 is also a light type which predominated in the U. P. epidemic tracts during 1946-47. Prior to the 1938-39 red rot epidemic, the Coimbatore strain (isolate *Poovan*) was the most virulent *C. falcatum* isolate amongst our collection [Chona, 1936]. During 1936-37, isolations made from *Shahabad Ponda* variety were found to possess greater virulence than isolate *Poovan* and this isolate was used for further tests, from 1937-38 to 1941-42.

In case of dark type *C. falcatum* isolates (*Poovan* and No. 3) the infection, generally speaking, was low, except in one season, 1937-38 when cultures of isolate No. 3 were highly sporing ; while with *C. falcatum* (isolate 78), representative of the light, type of *C. falcatum*, predominant in the epidemic areas of U. P. and northern Bihar the infection progressed very rapidly, particularly during the first two or three years, and the inoculated canes of several susceptible varieties, including Co. 213, 223, 299, 331, 373, 445, 526, Co. K 26, etc. dried up completely, as a result of red rot infection, about two months after inoculation.

Data regarding average linear spread of infection observed in the inoculated canes of the various varieties tested with *C. falcatum* isolates (*Poovan*, *Desi Ponda*, No. 3, No. 78 and No. 244) clearly showed that different cane varieties showed greatly varying degrees of resistance to red rot infection. The cane varieties like Co. 213, 223, 299, 331, 362, 373, 445, 526, Co. K. 26, 29, Co. S. 5, etc. proved highly susceptible in the various tests. Even with *C. falcatum* (isolate 3), which is not very virulent, these varieties showed the greatest amount of infection in the respective tests. Field observations in the epidemic areas fully bear out these results. P. O. J. 213 reported to be highly susceptible to red rot in Louisiana (U. S. A.) by Abbot [1938] has reacted as such in our red rot resistance tests. There are many varieties which showed a fair amount of resistance to red rot infection. Some of them are important commercial cane varieties, e.g. Co. 285, 313, 356, 393, 396, 419, 421, Co. S. 76, B.O. 4, etc. Others may have their importance for the Sugarcane Breeder as useful parent material for crossing work with a view to evolve red rot resistant varieties. The data (Tables I and II) also clearly show that the light type *C. falcatum* that predominated in the epidemic tracts of U. P. and Bihar during 1938-40, was much more virulent than the dark type *C. falcatum*, representative of the older, pre-1938-39 epidemic, *C. falcatum* flora of the country.

Of the 206 cane varieties and *Spontaneums* tested, 13 reacted as resistant, 82 as moderately resistant and 50 as susceptible. Remaining 61 varieties have not been tested for three seasons and thus need further testing.

The results of the varietal resistance tests (1938-49) are summarised in Tables I, II and III to give an idea, at a glance, of relative resistance to red rot of the various cane varieties tested with one dark type and two light type *C. falcatum* isolates. The reaction of the various cane varieties to the dark type (isolate 3) is presented in Table I and their reaction to the two light, highly virulent types (isolates 78 and 244) in Table II and III respectively. The varieties showing less than five inches of average linear infection per cane with the virulent isolates (No. 78 and 244) may be considered as highly resistant to red rot; those showing 5-15 inches infection as resistant; with 15-30 inches infection as moderately resistant; and those with more than 30 inches infection as susceptible. With the weakly parasitic isolates, like isolate 3, where the maximum linear spread of infection is much less, the boundaries of demarcation to assess the resistance to red rot of the varieties tested have to be drawn at slightly lower levels than those in the case of a virulent strain. These demarcations are, of course, purely arbitrary and any other values, bigger or smaller, could be assigned to them. But the point that has been kept in mind in fixing up the values assigned, is the percentage of the linear infection of a variety to the maximum linear infection obtained in that particular season, subject to a certain maximum. It is essential to keep it in relation to the maximum figure of the season as red rot development in the cane is greatly influenced by the weather and climatic conditions. These factors, being so highly variable, result in appreciable variation of red rot development in the inoculated canes from one season to another. These lines of demarcation have been fixed at 15 inches linear infection or 25 per cent of the maximum linear infection of the season, whichever is less, for resistant reaction; 15-30 inches linear infection or 50 per cent of the maximum infection of the season as moderately resistant and more than 30 inches linear spread or more than 50 per cent of the maximum infection obtained during the season as susceptible. Fifteen inches of linear spread of infection in five to six months time means a progress of attack of the disease in the inoculated canes at the rate of only about 2½-3 inches per month. From another point of view also, i.e. the economic loss (the percentage of cane tissue affected as compared to the total cane tissue), 2½-3 inches of linear spread per month only means about two or three per cent of the total length of the cane. The average length of cane in most of the commercial cane varieties is about 100 inches. It is hoped, therefore, that the linear infection standards fixed for judging the relative resistance or susceptibility of the cane varieties to red rot will be looked upon as reasonably correct.

Reaction to red rot of the various cane varieties tested during 1936-49, as judged by the above-mentioned standards, is summarised in Table IV following only broader classification as resistant, moderately resistant and susceptible.

TABLE I

Consolidated results of Red Rot Varietal Resistance Tests with C. falcatum *(isolate 3) carried out for four seasons (1938-42) at Karnal*

Average linear spread of infection (inches)	Cane varieties affected
0—3	Co. 393, Co. K. 28, K. 1279
3·1—6	Co. 214, 281, 285, 290, 313, 352, 356, 370, 371, 385, 386, 395, 412, 413, 421, 433, 434, 444, 529, 532, 548, 550, Co. K. 29, 30, Co. S. 5, 76, B.O. 4, K. 1164
6·1—9	Co. 244, 312, 331, 360, 396, 402, 411, 417, 419, 426, 432, 439, 441, 443, 464, 513, 524, 528, 540, 551, 554, Co. K. 22, 25,26, 27
9·1—12	Co. 459, 460, 465, 508, 547, 549, Co. K. 31, K. 1218, 1269
12·1—15	Co. 213, 373, 531, 553
15·1—18	Co. 299, Co. K, 32
18·1—21	Co. 362, 445, 526, 552
21·1—24	Co. 457, *Dehra Dun Ponda*
30·1—33	Co. 458, K. 1216

TABLE II

Consolidated results of Red Rot Varietal Resistance Tests with C. falcatum *(isolate 78) carried out for six seasons (1941-47) at Karnal*

Average linear spread of infection (inches)	Cane varieties affected
0—5	Co. 357
5·1—10	Co. 291, 353, 627, Co. K. 40, *Katha*
10·1—15	Co. 214, 285, 300, 349, 351, 355, 356, 393, 408, 419, 441, 444, 453, 466, 508, 513, 532, 534, 546, 547, 548, 549, 550, 555, 558, 565, Co. K. 28, 30, B.O. 4, C.P. 28/19, K. 1269, G. 1051, *Sunnabile*, *Narenga*, *Saccharum spontaneum*, (Burma), *Saccharum spontaneum* (Java)
15·1—20	Co. 205, 229, 243, 244, 270, 281, 290, 313, 352, 360, 370, 371, 395, 396, 402, 411, 413, 421, 432, 434, 443, 459, 462, 464, 465, 470, 475, 523, 524, 529, 543, 545, 551, 553, 554, 576, 617, 630, Co. K. 27, 39, Co. L. 5, 9, Co. S. 109, 146, C.P. 28/11, S. G. 201/1, S. C. 851, P.O.J. 2961, *Uba*, *Hemja*, *Kansar*, *Pansahi*, *Saccharum spontaneum* (Coimbatore)
20·1—25	Co. 300, 364, 385, 386, 412, 460, 463, 468, 476, 527, 531, 605, Co. K. 10, 22, 32 36, Co. L. 4, *Saretha*, *Kassoer*

(Table II continued on next page.)

TABLE II—(*contd.*)

Consolidated results of Red Rot Varietal Resistance Tests with C. falcatum (*isolate 78*) *carried out for six seasons (1941-47) at Karnal*

Average linear spread of infection (inches)	Cane varieties affected
25·1—30	Co. 312, 391, 433, 439, 474, 533, 537, 538, Co. K. 25, 31, 33, 37, Co. S. 5, P. 1587 C.A.C. 87, P.O.J. 1410, *Nargori*
30·1—35	Co. 331, 407, 467, 469, Co. K. 38, P.O.J. 1547, *Peshawar Ponda*, H.M. 661
35·1—40	Co. 426, 471, 557, Co. K. 26, 38, P. O. J. 1499
40·1—45	Co. 213, 362, 373, 472, 528, 552
45·1—50	Co. 361, Co. K. 35, *Uba Marrot*, *Surkha Saharanpuri*
50·1—55	Co. 223, 299, 457, 556
55·1—60	Co. K. 29
60·1—65	Co. 445, 473, 526

TABLE III

Consolidated results of Red Rot Varietal Resistance Tests with C. falcatum (*isolate 244*) *carried out for two seasons (1947-49) at Karnal*

Average linear spread of infection (inches)	Cane varieties affected
0—5	*nil*
5·1—10	Co. 440, *Sccharum spontaneum* (Coimbatore), *Saccharum spontaneum* (Burma), *Saccharum spontaneum* (Java)
10·1—15	Co. 301, 349, 352, 393, 408, 413, 421, 626, 631, 636, 653, 655, S. C. 851, Q. 813, *Chunnee*, *Sclerostachya*
15·1—20	Co. 214, 229, 243, 300, 356, 360, 371, 411, 412, 419, 443, 453, 467, 475, 523,524, 534, 546, 615, 620, 624, 627, 641, 654, G. 1051, *Uba*, *Hemja*, *Kansar*, *Katha*, *Saretha*, *Pansahi*
20·1—25	Co. 205, 244, 285, 290, 370, 385, 396, 402, 415, 426, 464, 508, 545, 617, 622 B.h. IX, P.O.J. 1410, 2878, 2961, Fiji B
25·1—30	Co. 270, 312, 313, 331, 432, 449, 527, 533, 605, 629, 630, S.G. 201/1, B. 3412, P.O.J. 2727
30·1—35	Co 213, 457, 469, 540, B. 247, B.h. V, C.A.C. 87, P.O.J. 2725
35·1—40	Co. 221, Q. 116
40·1—45	Co. 299
45·1—50	Co. 291,223, P.O.J. 1499, *Uba Marrot*
50·1—55	P.O.J. 213, S.G. 63/32

TABLE IV

Summary of the statement showing resistance and susceptibility to red rot of the various cane varieties tested at the I.A.R.I. during 1936-49

R—RESISTANT
M—MODERATELY RESISTANT
S—SUSCEPTIBLE
*—IMPORTANT COMMERCIAL CANE VARIETIES

Resistant			Moderately resistant									Susceptible					
Cane variety	Reaction (Different seasons)	No. of years tested	Cane variety	Reaction (Different seasons)	No. of years tested	Cane variety	Reaction (Different seasons)	No. of years tested	Cane variety	Reaction (Different seasons)	No. of years tested	Cane variety	Reaction (Different seasons)	No. of years tested	Cane variety	Reaction (Different seasons)	No. of years tested
Co. 349*	3R	3	Co. 205	4M-1R	5	Co. 434	3M-4R	7	Co. 551	3M-1R	4	Co. 213	2R-3M-8S	13	Co. 642	2S	2
Co. 356*	9R-4M	13	Co. 214	5M-6R-1S	12	Co. 439	4M-2R	6	Co. 553	2M-2R	4	Co. 221	2S	2	B. h. V.	2S	2
Co. 441	6R-2M	8	Co. 229	3M	3	Co. 442	3M	3	Co. 554	3M-1R	4	Co. 223	1R-2M-10S	13	C. A. C. 87	1M-2S	3
Co. 532	5R	5	Co. 243	2M	2	Co. 443	8M-2R	10	Co. 555	2M-1R	3	Co. 291	3S	3	Co. K. 25	3R-1M-2S	6
Co. 547	6R	6	Co. 244*	6M-6R	12	Co. 444	3M-3R	6	Co. 558	1M-2R	3	Co. 299	11S	11	Co. K. 26	1R-3M-2S	6
Co. 548	5R	5	Co. 281*	8M-3R	11	Co. 449*	4M	4	Co. 605	3M	3	Co. 312*	3R-8M-2S	13	Co. K. 29	4S	4
Co. 549	5R	5	Co. 285*	5M-8R	13	Co. 453*	2M-2R	4	Co. 617	3M	3	Co. 313*	6R-5M-2S	13	Co. K. 31	2M-2S	4
B. O. 4	5R	5	Co. 290*	11M-2R	13	Co. 459	2M-3R	5	Co. 627	1M-2R	3	Co. 331*	7M-6S	13	Co. K. 35	3S	3

TABLE IV—(*contd.*)

Summary of the statement showing resistance and susceptibility to red rot of the various cane varieties tested at the I.A.R.I. during 1936-49

Resistant			Moderately resistant									Susceptible					
Cane variety	Reaction (Different seasons)	No. of years tested	Cane variety	Reaction (Different seasons)	No. of years tested	Cane variety	Reaction (Different seasons)	No. of years tested	Cane variety	Reaction (Different seasons)	No. of years tested	Cane variety	Reaction (Different seasons)	No. of years tested	Cane variety	Reaction (Different seasons)	No. of years tested
Co. K. 34 . .	3R	3	Co. 300	3M	3	Co. 460	4M	4	Co. K. 10	3M-2R	5	Co. 361	1S	1	Co. K. 38	1M-2S	3
Chunnee . .	4R-2M	6	Co. 301*	1M-2R	3	Co. 461	3M-1R	4	Co. K. 22	4M-2R	6	Co. 362	1M-8S	9	H. M. 661	1M-1S	2
S. Spont. (Coimb.)	2R	2	Co. 352	4M-6R	10	Co. 462	2M-2R	4	Co. K. 27	3M	3	Co. 373	2R-4S	6	K. 1216	1S	1
S. Spont. (Burma)	2R	2	Co. 360	9M-1R	10	Co. 463	3M-1R	4	Co. K. 28	1M-2R	3	Co. 417	2M-8S	10	P. 1587	1M-2S	3
S. Spont. (Glagah, Java).	3R	3	Co. 370*	6M-3R	9	Co. 464	6M-2R	8	Co. K. 30*	2M-2R	4	Co. 426	3M-7S	10	S. G. 63/32	2S	2
			Co. 371	4M-3R	7	Co. 466	3M	3	Co. K. 36	3M	3	Co. 445	1M-6S	7	P. O. J. 213	2S	2
			Co. 385*	8M-2R	10	Co. 468	3M	3	Co. K 37	3M	3	Co. 457	1M-6S	7	P. O. J. 1547	1S	1
			Co. 386	4M-2R	6	Co. 475*	3M-1R	4	Co. K. 39	2M-1R	3	Co. 458	4S	4	P. O. J. 1499	3S	3
			Co. 393*	2M-5R	7	Co. 508*	5M-5R	10	Co. S. 5	3M-2R	5	Co. 467*	1M-2S	3	P. O. J. 2725	2S	2
			Co. 395*	4M-2R	6	Co. 513*	4M-5R	9	Co. S. 76*	2M-4R	6	Co. 469	2S	2	*Striped Mauritius*	1S	1

(Table IV continued on next page.)

TABLE IV—(*contd.*)

Summary of the statement showing resistance and susceptibility to red rot of the various cane varieties tested at the I.A.R.I. during 1936-49.

Resistant		Moderately resistant						Susceptible			
Cane variety	Reaction (Different seasons) / No. of years tested	Cane variety	Reaction (Different seasons) / No. of years tested	Cane variety	Reaction (Different seasons) / No. of years tested	Cane variety	Reaction (Different seasons) / No. of years tested	Cane variety	Reaction (Different seasons) / No. of years tested	Cane variety	Reaction (Different seasons) / No. of years tested
		Co. 396*	4M-3R / 7	Co. 523	3M / 3	G. 1051	2M-1R / 3	Co. 471	1S / 1	*Uba Marrot*	3S / 3
		Co. 402	6M-3R / 9	Co. 524	6M-3R / 9	S. C. 851	2M-1R / 3	Co. 472	2S / 2	*Surkha saharanpuri*	1S / 1
		Co. 408	1M-2R / 3	Co. 527*	4M / 4	P.O.J.1410	3M / 3	Co. 473	2S / 2		
		Co. 411	5M-6R / 11	Co. 529	3M-4R / 7	P.O.J.2961	3M / 3	Co. 474	1M-1S / 2	*Dehra Dun Ponda.*	3S / 3
		Co. 412	10M-2R / 12	Co. 531	4M-2R / 6	*Hemja*	3M-2R / 5	Co. 526	7S / 7	*Peshwar Ponda*	1S / 1
		Co. 413*	6M-5R / 11	Co. 533	4M / 4	*Pansahi*	2M-3R / 5	Co. 528	3M-4S / 7		
		Co. 419*	6M-6R / 12	Co. 534	2M-1R / 3	*Saretha*	5M-1R / 6	Co. 540	1S / 1		
		Co. 421*	8M-5R / 13	Co. 545	3M-1R / 4	*Uba*	3M-1R / 4	Co. 552	2M-1S / 3		
		Co. 432	7M-3R / 10	Co. 546	5M-4R / 9			Co. 556	3S / 3		
		Co. 433	4M-2R / 6	Co. 550	1M-2R / 3			Co. 557	1M-2S / 3		

Discussion

Method of testing. It would be evident from the perusal of literature [Martin, 1948 ; Dillewijn, 1946 ; Symposium on Disease Resistance Tests on Sugarcane reported in the Proceedings of the 5th and 6th Congress, International Society of Sugarcane Technologists, 1935 and 1938 respectively] that the systematic testing of sugarcane varieties against red rot and evolving of red rot resistant varieties is being done only in the U. S. A. at Louisiana and Canal Point, Florida. The other cane breeding stations situated in the Tropics and evolving varieties suitable for tropical tracts did not have to pay any special attention to red rot, this being only a minor disease with them. Even in Australia, where the cane tract is situated in the sub-tropical zone, red rot is not so serious a disease as Fiji disease, gumming, leaf scald, red stripe and downy mildew for which suitable methods for disease resistance tests have been evolved [Bell, 1935].

For testing red rot resistance of canes the methods employed in the U. S. A. by Edgerton and Moreland [1920], Edgerton and Tims [1935], Rands, Abbot and Summers [1935] and Abbot [1935 and 1938] mainly consist of inoculating the cut canes with *C. falcatum* and noting the progress of infection in the inoculated canes ; or inoculating the seed cuttings just before planting and then watching the progress of the disease. The choice of this method of testing for red rot resistance, i.e. with cut canes, by the American workers is obviously based on the fact that under the local conditions there red rot is mainly a disease of seed-cane, and as stated by Brandes [1935] " Red rot was not serious in standing cane except in southern Florida and that only in a few varieties, particularly P. O. J. 2714 ". To quote Abbot [1938] " Because of the great importance of red rot as a seed-cane disease this point is particularly stressed, and the classes of resistance have been defined with special reference to this type of injury ". But in India red rot is chiefly a disease of the growing cane crop [Butler, 1918 ; Venkatraman, 1935 ; Chona and Padwick, 1942]. In several other countries as well, e.g. Australia, Philippines, Mauritius, red rot is the disease of the growing crop and not of seed-cuttings. To quote Bell [1935] " In Queensland, red rot was a disease of standing cane and it did not affect germination to any great extent ". Ocfemia [1938] also states that " In Philippines, the disease (red rot) does not affect the germination of the cane points as does the Pine-apple disease. Red rot infects the stalks and the leaves through injuries caused by insects and by mechanical means ". Similarly in Mauritius, according to Wiehe (1947), " Locally, red rot affects only growing canes ; no healthy cuttings having been observed to be attacked after plantings ". In view of the greatly controversial results obtained by the various workers in India and the Western hemisphere, engaged in the study of red rot of sugarcane, Edgerton and Moreland [1920] stated that " From the various publications on the subject it is evident that for some reason or the other in India conditions are radically different from those in West Indies and the southern United States ".

The resistance of growing canes to red rot, being different to that of cut canes of the same variety, has been observed by several workers. Edgerton and Moreland [1920] state that " *C. falcatum* develops in the cane after cutting rapidly than it does

in growing canes". Edgerton and Tims [1935] stated that "The rate of growth of the fungus (*C. falcatum*) in the cut stalks may also vary considerably from that in a standing stalk". Abbot [1935] stated that "It appears from observations that C. P. 807 and Co. 290, and perhaps other varieties as well, are more resistant to red rot when growing than when in a dormant condition". Then again [Abbot, 1938] stated that "The red rot resistance of the growing plant possessed by some varieties, notably C. P. 807, is also important. Red rot spreads rèlatively little in vigorously growing C. P. 807, whereas in semi-dormant seed cuttings spread is very rapid". Abbot [1935] concluded that "It appears from the foregoing that while laboratory tests of susceptibility to red rot (on cut canes) give a measure of internal tissue resistance, they do not necessarily indicate the reaction of that variety to the disease under field conditions". Similarly Edgerton and Tims [1935] state that "To come to any conclusion then, in regard to susceptibility to red rot, stalks must be inoculated both in the field and in the laboratory". The latter (inoculation of cut canes) will be necessary only if the red rot trouble is that of the seed rot.

In view of the above-mentioned facts and that the red rot under local conditions in India is the disease of the growing crop and the resistance of growing canes is quite different from that of the cut canes, it is essential that to get a true picture of the behaviour of cane varieties to red rot, inoculations should be made on growing canes, in large enough number to counteract inevitable variability of results under field conditions; and the experiment should be allowed to run for five to six months to allow full scope for the development of the disease in the inoculated canes. In Formosa also, according to Kiryu [1940], the method adopted for testing varietal resistance of sugarcane to red rot is that of inoculating the growing canes.

There is, however, one drawback in this method of testing: the cane rind is wounded and the inoculum is placed straight away in the interior of the cane, thus doing away with the resistance that cane plant might have offered to the entry of the fungus into the cane. The fungus may progress rapidly within the cane once it reaches the interior cane tissue but may not be able to effect the entry easily. With this point in mind and the results obtained in the experiments of red rot infection through infected soil or irrigation water and through the nodal regions of the cane, namely, that the ten cane varieties under test in these experiments showed appreciable differences in the amount of infection produced in each, experiments were elaborated from 1942-43 season onward to test the relative resistance of a large number of cane varieties to red rot infection through soil, irrigation water and the nodal regions of the cane. The results obtained are being presented in a separate paper. Certain varieties which had reacted as susceptible to linear spread of infection, once the red rot organism had gained entrance as in the Plug Method inoculations, showed considerable resistance to infection through the nodal region and may thus stand well in spite of red rot infection all around them in an epidemic tract. Such varieties, as stated by Edgerton and Tims [1935] should be considered as resistant to red rot. These three other methods for testing varietal resistance against red rot are superior to the Plug Method in that, these do not involve any deliberate wounding of the cane plant for inoculation and the mode of infection is more natural. These methods

may be reliably employed for testing field-resistance of cane varieties to red rot. Furthermore, these testing methods are less laborious. But to have an idea of true inherent resistance of a cane variety which is essential for the selection of parent cane material for breeding red rot resistant varieties, the Plug Method is the only sure test.

Choice of isolate. The proper selection of the *C. falcatum* isolate to be used in these varietal resistance tests is obviously of utmost importance. The possibility of existence of *C. falcatum* strains of varying virulence was kept in mind from the very beginning of the red rot resistance tests. *C. falcatum* isolates from different cane varieties and localities were always studied for their virulence and only the most virulent one, available in our collection, was always used for the varietal resistance tests. Prior to the 1938-39 red rot epidemic in eastern U. P. and northern Bihar tract, only dark type *C. falcatum* isolates were met with in the various isolations which were not very highly virulent. During the epidemic two morphologic races, one light coloured with profuse sporulation and the other dark coloured and sparsely sporing, similar to the old pre-epidemic type, were met with [Chona and Padwick, 1943]. The light type was found to be highly virulent and was selected and used in the red rot varietal resistance tests for about six seasons (1941-47); when its virulence was found to be falling off and it was replaced in further tests, of the last two seasons (1947-49), with a fresh virulent isolate obtained from the 1946-47 red rot epidemic areas of U. P. The existence of physiologic forms of the red rot fungus, *C. falcatum* Went, certainly further complicates the work of varietal resistance tests. But the physiologic specialization is, fortunately, not of a very high degree. A large number of *C. falcatum* isolates obtained from different varieties and localities have been tested. The differences in the various isolates are mainly of their virulence. Little specificity has been observed between the isolates and cane varieties. A virulent isolate has been found to be comparatively more virulent on all the varieties. Generally speaking, the light type isolates are more virulent than the dark type. Similar results are reported by Tims and Edgerton [1932]. Even Abbot [1938] himself, who was the first to envisage the existence of physiologic forms in *C. falcatum* [Abbot, 1933], states that " The differences between the isolates or groups of isolates in these tests (virulence comparison tests of *C. falcatum* isolates) do not represent the high degree of specialization demonstrated in the rust fungi "........ "To a certain degree these differences on all the varieties thus far tested are associated with the differing morphological characters, the isolates of the light cultural race, in general, being more virulent than those of the dark ". The results obtained, therefore, by testing with one isolate, provided it is a highly virulent one, are likely to hold good. Special attention has always been paid to this point of proper selection of *C. falcatum* isolate for varietal resistance tests. To quote Abbot [1938] once again : " As a rule, however, varieties classed as resistant or susceptible to one isolate have not had their classification changed when tested with larger number of isolates ".

One more point, however, has to be kept in mind, i.e. the maintenance of the selected isolate in a pure form, as some of the isolates have been found to mutate in the culture. The fungus after a few subculturings may be quite different from

the parent culture, both morphologically as well as in pathogenicity. *C. falcatum* (isolate 3) was fairly virulent when first isolated and gave a good amount of infection during 1937-38 varietal resistance test. But within one year of subculturing on artificial synthetic medium it had lost most of its virulence and the amount of infection it produced on the same cane varieties during the 1938-39 test was much less. Isolate 78 remained unchanged for several seasons but a gradual decline in its virulence was noticed. Chona and Hingorani [1950] have shown that mutation in *C. falcatum* occurs more frequently on a rich medium like Richards' and in older cultures.

Resistance and susceptibility rating. The standards fixed to assess the resistance or susceptibility of the cane varieties tested have been already discussed fully in the text. Linear spread of infection of the inoculated canes has been used as the criterion for judging the resistance or susceptibility of varieties. In view of the appreciable variation of infection from cane to cane and from one season to another, the average linear spread of infection in the inoculated canes, which must be sufficiently large in number (about 50 canes), and then the over-all average of at least three seasons results, particularly for declaring a cane variety as resistant, are considered essential.

It might, however, be mentioned that as no cane variety, possessing desirable commercial requisites, is absolutely immune to red rot ; adequate care to keep the seed stocks free from gradual accumulation of the disease would be necessary, even if resistant varieties are grown. This can be easily achieved by maintaining special seed plots advocated by Chona [1943] and following a few simple practical schedules for the control of red rot [Chona, 1947].

The future crossing work. Even greater than the immediate practical importance of the results of varietal resistance tests reported in the paper regarding the reaction to red rot of the various important commercial cane varieties and promising agronomic selections, is the future line of work now made possible, i.e. of greater utilization of cane varieties and *Saccharum* sp. possessing high degree of resistance to red rot in the Cane Breeding Programme. A glance at Table IV will reveal that certain cane varieties and *Spontaneums* have proved highly resistant to red rot in each of the tests during several seasons. Some of these have been selected to effect about a dozen crosses at the Sugarcane Breeding Station, Coimbatore, with the kind collaboration of the Government Sugarcane Expert and the progenies of each of these crosses are being tested for red rot reaction, in order to select the varieties which freely transmit their red rot resistance character to a larger proportion of the progeny. It is thus hoped that in due course it may be possible to evolve cane varieties which, besides possessing the requisite commercial qualities of good growth habit, good yield and high sucrose percentage, are also resistant to red rot.

Summary

The red rot epidemics of sugarcane crop in India during 1938-40 and 1946-47 are briefly described and the necessity of cultivation of only such cane varieties that possess sufficient degree of resistance to red rot is stressed.

The results of Red Rot Varietal Resistance Tests carried out during 1936-49 are presented and the reaction to red rot of the 206 varieties tested are given in tabulated form.

The method of testing for red rot resistance and assessing red rot resistance and susceptibility rating, are discussed. Future lines of work for evolving red rot resistant varieties are indicated.

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RESPONSE OF BERSEEM TO FERTILIZERS AND COMPARISON OF AFTER-EFFECTS WITH THOSE IN CEREALS

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The problem of phosphate manuring of crops has been under investigation from the very inception of the Institute. The early workers made extensive studies on the mobility of phosphate in the calcareous soils of Pusa. Different formulae and combinations were tried with various crops and the results indicated poor response from cereals. In the year 1940, however, a new programme of phosphate manuring of legumes was launched and the results obtained during the last decade have supplied very valuable information. Of all the legumes tried for the purpose, the most remarkable response was from berseem (*Trifolium alexandrinum*) as shown by Parr and Bose [1944], Sen and Bains [1951], and Khan [1952]. This may, perhaps, be due to specialised nature of nodule bacteria found on the roots of this crop which are generally stimulated by phosphate.

The investigation reported in this paper, shows yet another aspect of improving soil fertility through the use of legumes and fertilizers for getting better return from subsequent crops.

Experimental

This experiment was strated in *rabi* 1948 on a plot of land situated in the middle block of the Indian Agricultural Research Institute farm at New Delhi.

Soil

The soil consisted of sandy loam with rather low fertility having a *p*H ranging from 6·8 to 7·2. An idea of the physical and chemical composition may be had from Tables I & II.

Table I

Percentage physical composition

Soil separate	Depth	
	0-1 ft.	1-2 ft.
Sand	80	80
Silt	10	10
Clay	10	10

TABLE II

Percentage chemical composition

Nutrients	0—3 in.	Depth 3—6 in.	6—12 in.
Noitrogen	0·0570	0·0522	0·0404
Phosphoric acid	0·1078	0.1038	0·0897
Potash	0·4419	0·4062	0·3963

Lay-out. The experiment was laid out according to 6×6 latin square design.

Treatments

	Dose per acre: To legume (berseem)	Dose per acre: To cereals (maize and wheat)
A.	No fertilizer	Ammonium Sulphate at 40 lb. N per acre
B.	Superphosphate at 120 lb. P_2O_5	-nil-
C.	Ammonium sulphate at 40 lb. N+superphosphate as in B	-nil-
D.	Ammonium sulphate at 40 lb. N + Super. 120 lb. P_2O_5 + Pot. sulphate 80 lb. K_2O.	-nil-
E.	Super. 120 lb. P_2O_5 × Potassium sulphate 80 lb. K_2O	-nil-
F.	No manure	Control

Rotation. A two-year rotation of fallow-berseem-maize (fodder)-wheat was adopted. This was run for two cycles of rotation.

Results. The experimental results obtained with different crops are as given below :

(*a*) *Berseem*

The yield ot berseem todder (total of five cuttings) for different treatments is given in Table III.

TABLE III

Yield of berseem fodder in maunds per acre

Treatment	1948-49		1950-51		Mean yield (combined analysis)
	Yield in md. per acre	Per cent increase or decrease over control	Yield in md. per acre	Per cent increase over control	
A	556·51	—1·28	353·20	2·10	454·85
B	708·78	25·74	771·93	123·13	740·35
C	766·02	35·89	788·42	127·91	777·22
D	810·24	43·74	832·08	140·53	821·16
E	775·23	37·53	813·34	135·11	794·28
F	563·70	..	345·94	..	454·82
Mean	696·75	..	650·82	..	..
Response	Sig.	..	Sig.	..	Sig.
S. Em±	20·91	..	33·13	..	42·35
C. D. (5 per cent)	120·80	..	97·62	..	123·83

From Table III it is evident that the differences between fertilizer treatments do not among themselves exist, they are superior over control (F and A). It is, therefore, obvious that fertilization of legume with phosphate, alone or in combination with nitrogen and potash, is advantageous and the highest yield was obtained with complete minerals (NPK).

The increase in yield with this treatment was of the order of 44 and 140 per cent respectively in the different years over control.

(b) *Maize (fodder)*

Berseem was followed by maize, Pusa yellow 2, for fodder. The comparable yields for 1949 and 1951 are given in Table IV.

TABLE IV

Yield of maize fodder for two years

Treatments	1949 (md. per acre)	1951 (md. per acre)
A	303·9	224·9
B	243·4	212·0
C	245·2	202·6
D	260·7	217·5
E	235·0	201·6
F	269·2	191·1
Response	Sig.	Not Sig.
S. Em+	14·7	11·5
C. D. at 5 per cent	43·25	..

Though the response is significant in the first and not in the second year, the trend is the same. In order to eliminate the effect of season and evaluate the overall behaviour of treatments the data were pooled and the results of combined analysis are summarised in Table V.

TABLE V

Mean yield of maize fodder

Treatments	Yield (maunds per acre)
A	264·4
B	227·7
C	223·9
D	239·1
E	218·8
F	225·6
Response	Sig.
S. Em±	11·08
C. D. at 5 per cent	32·6

The statistical analysis of the combined data showed that the treatments as also seasons had significant effect on the yields.

The interaction between seasons and treatments was not significant showing that the seasons did not favour any particular treatment.

It is, however, evident from the data that there exists no significant difference between the treatments A (direct application of 40 lb. nitrogen) and D (NPK to legume), while A is definitely better than others.

(c) *Wheat*

According to rotation maize was followed by wheat, NP 165, with the object of comparing the residual fertility with the direct manuring of wheat. The statement of yield can be seen in Table VI.

TABLE VI

Yield of wheat (N. P. 165) grain in maunds per acre

Treatment	1949-50 grain yield	Per cent increase over control	1951-52 grain yield	Per cent increase over control	Mean yield (combined analysis)
A	28·49	70·0	20·05	64·10	24·27
B	18·97	13·8	12·94	7·47	15·95
C	23·05	38·3	12·19	1·25	17·62
D	24·65	48·0	19·52	62·13	22·08
E	23·80	43·0	15·18	26·07	19·49
F	16·66	..	12·04	..	14·35
Response	Sig.		Sig.		Sig.
S. Em±	2·03		1·12		2·11
C. D. 5 per cent	5·98		3·31		6·23

The trend remains the same in both the years except a slight change of place between B and C. Also there was no significant difference between the direct application of nitrogen to wheat and the residual effect of NPK to legume. This indicates the dominant effect of residual carryover of fertility in not rendering the differences between A and D statistically significant though they are appreciable.

Table VII gives an idea of improvement in soil fertility with respect to various treatments.

TABLE VII

Nitrogen and carbon status of the soil and the C/N ratio

Treatment	After berseem		C/N ratio	After maize		C/N ratio
	Nitrogen (per cent.)	Carbon (per cent.)		Nitrogen (per cent.)	Carbon (per cent.)	
A	0·055	0·69	12·47	0·046	0·33	7·40
B	0·058	0·70	12·06	0·049	0·37	7·53
C	0·056	0·73	13·02	0·048	0·36	7·59
D	0·061	0·94	13·72	0·053	0·43	8·10
E	0·059	0·73	12·24	0·044	0·35	7·83
F	0·055	0·64	11·60	0·041	0·30	7·36

Table VII indicates the importance of fertilizers to legume not only in increasing the nitrogen and organic status of the soil after the legumes crop has been removed, but also its continuity until after an exhaustive crop like maize has been taken. The application of complete minerals to legumes has even maintained higher nitrogen and organic status in the soil than the direct application of 40 lb. nitrogen per acre. This may be due to larger residues, rich in nitrogen, obtained by the soil through legumes rather than the cereals. It is, therefore, obvious that fertilizers play an important role not only in increasing the yield of legume but also building up of fertility.

DISCUSSION

(*a*) *Berseem.* The most outstanding results in both the seasons were obtained by the fertilization of legume with phosphate either alone or in combination with nitrogen and potash. The greater yield of berseem may be attributed to higher nitrogen fixation by it. Increased yields of legume were also obtained by Hayman [1943] and Roberts [1943] due to manuring. The phosphate manuring of legumes increases the nodulation and the nitrogen content of the soil. Increase in bacterial action, weight of plants and total dry matter of legume crop was also noted among others by Hutchison [1923], Taggart [1931], Parr and Bose [1944-45], Mercar [1948], Bartholomew [1950] and Sen and Bains due to phosphate manuring of legumes.

The highest yield obtained under complete minerals may perhaps be due to balanced nutrition, as legumes feed heavily on the phosphates and potash. These findings are corroborated by Gericks [1944] and Davis, *et al.*, [1945].

(*b*) *Maize.* The overall response was highly significant at one per cent. level. Both direct application of mineral nitrogen and the residual effect of NPK fertilizers did not show significant differences though the former was significantly superior over others and the latter was not different from the rest. This may, perhaps, be due to larger food reserves (Table VII) under D, which enabled it to give profitable

response. Such an effect was also noticed by Dumeriel [1950] and Mutir Gilbert [1951].

From the above results it is evident that under a cropping system where maize follows fertilized (NPK) berseem the direct application of nitrogenous fertilizer to it may perhaps be not necessary.

(c) *Wheat.* Even in the case of a second crop of wheat the residual effect of fertilized (D) berseem was pronounced. The trend ot yield was no different from the previous crop. Also the results were almost the same in both the seasons, except a slight change of place between B and C. The additional dose of 40 lb. nitrogen per acre on wheat could not produce a significantly higher yield over the residual fertility built with 'D' in the rotation.

Summary and conclusion

Not only good fodder was produced under treatment D (complete minerals to berseem) but also the fertility of the land was built up.

From the point of economics also the system is sound as the additional cost of fertilizers applied to berseem was more than paid in the form of higher returns obtained from it. The conclusion which can be drawn from this study is that the practice of applying minerals to berseem for raising its yield and those of subsequent crops is sound and should be recommended.

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STUDIES ON THE NUTRIENT DEFICIENCY SYMPTOMS IN PLANTS

I. EXPERIMENTS WITH BERSEEM (*TRIFOLIUM ALEXANDRINUM*)

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According to Wallace [1951][1] the basis of the method for determining mineral deficiencies in plant, from the visual deficiency symptoms, is that, plants seriously deficient in any mineral nutrient develop well defined and characteristic signs of these conditions in various organs. A particular nutrient deficiency or excess produces specific effects on plant organs and accordingly the effects produced by it over a wide range of plants often have more or less similar characteristics. The deficiency symptoms of N, P, K and Mg appear usually first in the older parts of the plants, while Ca, Fe and B deficiency symptoms appear at the growing points. Before this method can be of value, specific symptoms for each deficiency and for each kind of plant must be established. This is usually done by recording the visual deficiency symptoms produced by growing plants in controlled, sand and water culture experiments. The symptoms are checked by comparison with instances of deficiencies in field and pot experiments proved to be due to the same causes.

Morgan [1939] studied nutrient deficiencies of green-house soils using tobacco as an indicator plant. Jones [1931] discussed the diagnostic value of plant symptoms in determining nutrient deficiencies in soil. Nicholas, Jones and Wallace [1945] conducted experiments on the control of magnesium deficiency in green-house tomatoes. Wallace [1951][2] described with the aid of colour photographs the various deficiency symptoms in most of the agricultural crops and fruit trees.

In the present investigation, attempts have been made to examine how far the visual deficiency symptoms observed in selected indicator plants can indicate the mineral deficiencies in the soil. The studies were restricted to Delhi and Pusa soils, as it was possible to confirm the information thus obtained with controlled pot culture and field experiments in progress for a number of years at both these places. The investigations yielded useful data with chemical, micro-biological and plant physiological methods as applied to Pusa soils [Sundara Rao, 1948]. As reddening of leaves is normally observed in berseem fields in some parts of Delhi State, it was thought desirable to make a detailed study of the underlying causes of the phenomenon in pot culture experiments, conducted with Delhi Soil.

Materials and Methods

Chemical analysis of the soil samples were carried out according to the methods recommended in the Official and Tentative Methods of Analysis [A. O. A. C., 1940] and the mechanical analysis was done by the International Method as described by Piper [1944].

Pot culture studies were conducted first in *rabi* 1946-47 using berseem as an indicator plant. A representative sample of the soil (surface 0-9 in.) from the field was collected. About 5 lb. of gravel was put in each pot to favour aeration and the soil was put in with moderate packing. Thirty pounds of air-dry soil sieved through a 5 mm. sieve was mixed thoroughly with the various fertilizers and 3 lb. of water. The fertilizers were added on weight basis calculated by taking the weight of an acre of 6 in. surface soil equal to two million pounds. Berseem seed was inoculated with legume culture and was sown at the rate of 25 seeds per pot. The moisture was maintained at about 10 per cent level till germination was complete. The number of plants was ultimately thinned to 12 per pot. The pots were regularly watered every alternate day with about 1½ lb. of water per pot.

Preliminary experiment

The soil, used in *rabi* 1946-47 experiment, was collected from Main Block 11 (Plot B) of the Indian Agricultural Research Institute farm. In 1945 *kharif*, this land was green-manured with sunhemp, followed by oats in *rabi*. Next *kharif* it was sown to maize. The soil was found to be at a fairly high level of fertility as judged by the yields of various rotational crops. The soil analysis data are given in Table I.

TABLE I

Chemical and mechanical composition of soil from Main Block 11(B) (on oven-dry basis)

Chemical analysis		Mechanical analysis	
Loss on ignition	2·03 per cent	Coarse sand	6·3 per cent
Total nitrogen	0·058 „	Fine sand	47·7 „
Available P_2O_5 (Citric acid soluble)	0·027 „	Silt	23·6 „
Nitrate -N (per 100 gm. soil)	1·04 mg.	Clay	19·2 „

The treatments consisted of : (1) No manure, (2) ammonium nitrate at 20 lb. N and sulphate of potash at 50 lb. K_2O per acre, (3) to (7) superphosphate at 50, 100, 150, 200 and 250 lb. P_2O_5 per acre, respectively over a basal dressing as under treatment (2). Each treatment had six replications but under the no manure treatment there were only three pots.

Nutrient deficiency symptoms in plants were not observed in any of the above treatments. Reddening of few leaves of one or two plants was observed in some of the treatments. The data obtained indicated that the soil containing 0·027 per cent available P_2O_5 could not usually be considered deficient in phosphates. However, the amount of available phosphates was not sufficient to meet the full requirement of the legume and an application of 150 lb. P_2O_5 per acre was found to be necessary

to meet the additional demands of the crop for vigorous growth, as may be seen from the yield data in Table II.

TABLE II

Summary of results—Yield of berseem fodder

Treatments	Average dry yields in gm. of berseem per fodder pot Total of 4 cuttings	S.E.
1. No manure	16·45	2·50
2. NK	17·78	1·53
3. NK P_{50}	18·77	1·53
4. NK P_{100}	22·28	1·53
5. NK P_{150}	26·22	1·53
6. NK P_{200}	26·32	1·53
7. NK P_{250}	27·84	1·53

For comparing 'No manure' with any of remaining treatments critical difference at 5% level=5·14
For comparing any two of the treatments 2 to 7 critical difference at 5% level = 4·45

Treatment '7' gave significantly higher yields of fodder than treatments '1', '2' and '3'. The differences in the yield of fodder between treatments '5', '6' and '7' were not significant. The application of 150 lb. P_2O_5 per acre appear to be about the most useful dose of the fertilizer.

In the beginning of winter of 1947-48, a fresh series of pot-culture studies were conducted with two soils collected from different parts of the Institute farm. The first soil, low in available P_2O_5 was collected from the non-experimental area in the Top Block and the second soil, richer in available P_2O_5 was collected from the Main Block 11 (Plot D—unmanured area).

DATA AND DISCUSSION

The data on chemical and mechanical analysis of the two soils are given in Table III. The Top Block soil is designated as Soil I and the Main Block soil as Soil II.

The most important of the differences between the two soils was their available phosphate content.

The following treatments were applied:

Experiment I (Soil I)

A. Superphosphate at the rate of 0, 50, 100, 200 and 250 lb. P_2O_5 per acre respectively.

B. Superphosphate in the above 6 doses with a basal dressing of $N_{20}K_{50}$ (ammonium nitrate @ 20 lb. N and potassium sulphate @ 50 lb. K_2O per acre).

C. Superphosphate as in 'A', with a basal dressing of N_{60} K_{150}.

D. N_{20} ; K_{50} ; $N_{20}P_{150}$; $P_{150}K_{50}$.

TABLE III

Soil analysis data

(percentages on oven-dry basis)

	Chemical constituents		Mechanical composition		
	Soil I	Soil II	Constituent	Soil I	Soil II
Total N	0·047	0·054			
Loss on ignition	2·26	4·56			
Total P_2O_5	0·07	0·07			
Total K_2O	0·62	0·65	Coarse sand	16·5	16·7
Total CaO	0·89	0·71	Fine sand	45·8	43·7
Available P_2O_5 (Citric acid sol.)	0·003	0·023	Silt	10·4	10·9
Available K_2O (Citric acid sol.)	0·013	0·012	Clay	18·5	17·5
Organic carbon	0·31	0·30			
Nitrate—N	0·5 mg. per 100 gm. soil	0·9 mg. per 100 gm. soil			
*p*H	7·7	7·4			

Experiment II (Soil II)

E. Superphosphate at the rate of 0, 100, 150, and 200 lb. P_2O_5 per acre respectively.

F. Superphosphate as under 'E' with a basal dressing of $N_{60}K_{150}$.

Each treatment was replicated four times in both the experiments.

Inoculated berseem seed was sown during the beginning of November 1947. The plants were thinned in two stages and ultimately 12 plants per pot were kept. Four cuttings were taken, the first after two months of growth and others approximately at monthly intervals. The pots were watered regularly. After each cutting the yield of dry matter was estimated.

Reddening symptoms were observed in plants grown in Soil I, more prominently in pots receiving no P_2O_5 or receiving P_2O_5 at a rate less than 200 lb. per acre. Table IV shows the percentage of plants showing the reddening symptoms in each treatment before the first cutting was taken. For these studies, crop showing 10 per cent or less of affected plants was considered as a normal crop. This was supported by the statistical examination of the data on the reddening percentages of the plants.

TABLE IV

Reddening of berseem plants

Treatments	Reddening of leaves in per cent	Treatments	Reddening of leaves in per cent
Expt. I (Soil I)			
A. No manure	40	C. $N_{60}K_{150}$ P_0	34
P_{50}	25	,, P_{50}	19
P_{100}	24	,, P_{100}	14
P_{150}	24	,, P_{150}	9
P_{200}	2·5	,, P_{200}	1
P_{250}	*nil*	,, P_{250}	1
B. $N_{20}K_{50}$ P_0	41	D. N_{20}	33
,, P_{50}	24	K_{50}	19
,, P_{100}	19	$N_{20}P_{150}$	13
,, P_{150}	15	$P_{150}K_{50}$	14
,, P_{200}	10		
,, P_{250}	6		
	SE_m : $\pm$ 4·46		
Expt. II (Soil II)			
E. No manure	14	F. $N_{60}K_{150}$ P_0	20
P_{100}	15	,, P_{100}	9
P_{150}	10	,, P_{150}	4
P_{200}	5	,, P_{200}	3
	SE_m : $\pm$ 3·20		

Thus, with the soil poor in available P_2O_5 (Experiment I) highly significant decrease in reddening occurred both with a dose of 200 lb. P_2O_5 per acre, with or without a basal dressing of $N_{20}K_{50}$ and with a dose of 150 lb. P_2O_5 per acre with a basal dressing of $N_{60}K_{150}$. With unmanured soil (Experiment II) rich in available P_2O_5, the plants showing reddening symptoms were one-third of those observed in soil containing low available P_2O_5. Two hundred pounds P_2O_5 per acre without basal dressing and 150 lb. P_2O_5 per acre with a basal dressing of $N_{60}K_{150}$ were the doses

wherein only 5 per cent and 4 per cent of the plants showed reddening symptoms. The soil richer in available P_2O_5 content (Soil II) had in general, considerably less number of affected leaves than the soil poor in available P_2O_5.

After the first cutting was taken, the reddening symptoms in berseem practically disappeared and the number of plants showing these symptoms did not exceed 2 per cent in any of the treatments.

The yield data of berseem crop for the four cuttings are given inTable V.

TABLE V

Yield of berseem fodder

Treatments	Average yield of fodder in gm. per pot (oven dry)	Treatments	Average yield of fodder in gm. per pot (oven dry)
Expt. I (with Soil I)			
A. No manure	9·4	C. $N_{60}K_{150}$ P_0	12·4
P_{50}	16·0	,, P_{50}	18·7
P_{100}	18·9	,, P_{100}	20·5
P_{150}	17·0	,, P_{150}	22·6
P_{200}	18·9	,, P_{200}	21·8
P_{250}	23·8	,, P_{250}	23·9
SE_m : ± 1·40		SE_m : ± 1·79	
C. D. at 5% : 4·17		C. D. at 5% : 5·33	
B. $N_{20}K_{50}$ P_0	10·1	D. N_{20}	10·9
,, P_{50}	16·9	K_{50}	9·9
,, P_{100}	20·5	$N_{20}P_{150}$	19·7
,, P_{150}	20·1	$P_{150}K_{50}$	18·1
,, P_{200}	17·0		
,, P_{250}	19·4		
SE_m : ± 1·08		SE_m : ± 0·68	
C. D. at 5% : 3·22		C. D. at 5% : 2·05	
Overall analysis :—SE_m : ± 1·29			
C. D. at 5% : 3·64			
Expt. II (with Soil II)			
E. No manure	26·0	F. $N_{60}K_{150}$ P_0	27·6
P_{100}	32·5	,, P_{100}	30·8
P_{150}	31·5	,, P_{150}	36·4
P_{200}	32·3	,, P_{200}	40·4
SE_m : ± 2·15		SE_m : ± 2·48	
C. D. at 5 % : 6·63		C. D. at 5% : 7·49	

The correlation co-efficients between yield and percentage reddening of berseem plants of the two experiments were worked out and were found to be non-significant. The values of the co-efficients of correlation were *—0·0347* and *—0·0298* for experiments I and II, respectively.

The reddening symptoms of berseem leaves were more marked in the early stages when the plant was not sufficiently well-developed to draw the necessary nutrients from the soil. Similar reddening was observed in the lysimeter experiments (Desai, Sundara Rao and Tejwani, 1953) and in field trials conducted at the Indian Agricultural Research Institute farm. The reddening of leaves at the early stages of the crop cannot, therefore, be considered as due to seasonal effects.

Soil I

In the series without basal dressing, superphosphate treatment at 50 lb. P_2O_5 per acre and above gave significantly increased yields over 'no manure'. The differences between P_{50}, P_{100}, P_{150} and P_{200} were small and were not statistically significant. The treatment P_{250}, however, gave increases in yield significantly higher than other treatments. This deviation from the normal yield curve may be due to the effect of additional nitrogen fixed when P_2O_5 was applied at the rate of 250 lb. per acre.

With a basal dressing of $N_{20}K_{50}$, the optimum effective dose of P_2O_5 was 100 lb. per acre. The differences between the yields due to P_{100}, P_{150}, P_{200} and P_{250} treatments were not statistically significant.

In the series with a basal dressing of $N_{60}K_{150}$, P_{50} treatment gave significant difference in yield over that with the basal dressing only. Treatments with superphosphate at 50, 100 and 200 lb. P_2O_5 per acre did not bring about significant differences in the yield of fodder. The yield differences between treatments P_{100} to P_{250} were also not statistically significant.

No increase in the yield of berseem fodder over no manure was observed with $N_{60}K_{150}$ treatment. The inclusion of superphosphate was necessary to increase the yield over that of 'no manure'.

The treatment P_{250} alone was as good as the treatment $N_{60}K_{150}P_{250}$ which indicated that in the case of berseem, super alone at 250 lb. P_2O_5 per acre would be sufficient.

Soil II

In the series without a basal dressing of NK, the different doses of P_2O_5 applied did not increase the yields of berseem fodder significantly over that of 'no manure'. With a basal dressing of $N_{60}K_{150}$, P_{250} and P_{200} gave significantly increased yields over no manure and $N_{60}K_{150}$. With NK, P_{200} was significantly better than P_{100} but not over P_{150}.

Overall effects of P_2O_5 : Soil I

Statistical analysis of the overall effects of P_2O_5 and basal dressings are shown in Table VI.

TABLE VI

Overall effects of P_2O_5 and basal dressings

Treatments of P_2O_5 in lb. per acre	Yield of fodder in gm. per pot (oven-dry)
250	22·38
100	19·94
150	19·89
200	19·21
50	17·20
0	10·61
SE_m : ± 0·81	
C. D. at 5% level : 2·29	
Dressings per acre	
$N_{60}K_{150}$	19·98
$N_{30}K_{50}$	17·31
N_0 K_0	17·30
SE_m : ± 0·57	
C. D. at 5% level : 1·62	

GENERAL DISCUSSION

The red colour in leaves is due to pigments similar to anthocyanins formed inside the plants which some workers attribute to the improper carbohydrate metabolism. Since P addition was found to remove these symptoms appreciably, the reddening of berseem leaves is supposed to be caused by phosphorus deficiency.

In the soil poor in available P_2O_5, maximum yield was obtained with superphosphate applied at 250 lb. P_2O_5 per acre. The differences in yields of berseem between treatments P and PK and between those of NP and NPK were not significant. This indicates that at the levels of nitrogen and phosphate tried, the application of potassic fertilizer may not be necessary. Considering the main effects at 5 per cent level of significance, the effect of P was most significant and that of N at a dose of 60 lb. per acre was next in order. The remaining effects and interactions were found to be insignificant.

In the second soil, rich in available P_2O_5, a dressing of $N_{60}K_{150}$ plus an additional dose of P_{150} increased the yield significantly over the control, either of them alone being ineffective. This is in accordance with the general concept that in the fertile soils favourable response can only be obtained with heavy dose of balanced manures.

Summary

1. The reddening of berseem leaves is very marked in those soils of Delhi State which are poor in available phosphates. Experiments carried out in pots with soil poor in phosphates, indicated that the application of increasing doses of superphosphate progressively reduced the reddening symptoms and increased the yield of dry fodder.

2. In the soils rich in phosphates, the reddening of leaves was not conspicuous. Superphosphate alone did not lead to any increase in yield ; but with a basal application of a mixture of nitrogenous and potassic fertilizers at the rate of 60 lb. N and 150 lb. K_2O per acre, manuring with superphosphate upto a dose of 200 lb. P_2O_5 per acre gave a favourable response.

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PRELIMINARY TRIALS ON THE MANURING OF GRASS-LANDS IN BOMBAY STATE

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MANURING of grass-lands is extensively practised in foreign countries and there is no doubt that it is the quickest method of increasing the production of forage in Bombay State also. Not only the quantity but also the quality of grass can be improved by suitable manuring. Grasses are known to be highly responsive to nitrogen and in some tracts to phosphoric acid also. It is, therefore, essential to undertake experiments on the application of nitrogen and phosphate to grass-lands in the different climatic and soil regions of the State. At the suggestion of the Milk Commissioner, Bombay, preliminary experiments on manuring of grass-lands were undertaken from 1946 to 1949.

The experiments were laid out at the Government Dry Stock Farm at Palghar (District Thana) which is on the Western Railway, about 50 miles from Bombay. The area is a narrow strip of about five to ten miles width along the sea-coast and abounds in extensive grass-lands of which about five thousand acres are attached to the Government Dry Stock Farm, Palghar. The topography is undulating and the soil is an ash-grey clay loam, varying in depth from eight to ten inches to several feet. The soils of these areas are fairly well drained, the deeper ones cracking in summer producing columnar blocks. Their lime reserve is very low at the surface and the *p*H value varies from 6·5 to 7·5. Stray lime nodules are noticed in the deeper layers. The average annual rainfall is about 70 inches, the major part of which is received during July and August. Grass is usually harvested between October and December when at a maximum height of about five to six feet. The four major species of grasses found are:

(i) *Ber—Ischaemum aristatum* Linn.

(ii) *Moshi—Iseilema wightii* Anders.

(iii) *Phul—Themeda cymbaria* Hack, and

(iv) *Rohida—Eulalia argentea* Brogn.

Experimental

Manurial treatments. The following manurial treatments were tried in the experiments so as to find out the best dose and form of nitrogen in combination with phosphoric acid for application to grass-lands:

(1) No manure

(2) Farmyard manure supplying 30 lb. nitrogen per acre

(3) Groundnut cake supplying 30 lb. nitrogen per acre

(4) Farmyard manure plus sulphate of ammonia each supplying 15 lb. nitrogen per acre

(5) Groundnut cake plus sulphate of ammonia each supplying 15 lb. nitrogen per acre

(6) Farmyard manure supplying 60 lb. nitrogen per acre

(7) Groundnut cake supplying 60 lb. nitrogen per acre

(8) Farmyard manure plus sulphate of ammonia each supplying 30 lb. nitrogen per acre

(9) Groundnut cake plus sulphate of ammonia each supplying 30 lb. nitrogen per acre.

It was also decided to study the effect of superphosphate (supplying 40 lb. P_2O_5 per acre) alone and in combination with nitrogen.

Layout of experiment. A split-plot design was adopted for this experiment. The nine main plot treatments consisted of different doses and kinds of nitrogen together with a control of no manure ; each main plot was divided into two sub-plots to one of which superphosphate was applied at random. The randomisation of main plot and sub-plot treatments was carried out in 1946. In subsequent years the sites of the experiments with the relative position of the treatments were kept the same.

Plan of experiments. About 10 acres of land situated in the grass-land area of the Government Dry Stock Farm were selected. All the experimental area could not be laid out in one compact block, hence it was sub-divided into two sites, site I consisting of replications A, B, C and D and site II consisting of replications E, F, G and H. The experimental areas, each of 3·85 acres, for the two sites were marked out separately and within each area all the four replications with their main plots, sub-plots and requisite guard rings were marked. The net area of each sub-plot was 78 ft. × 14 ft. (one *guntha*) ; a ring of six feet was kept all round the plot making the grass sub-plot 90 ft. × 26 ft. Before starting the experiment, the area was fenced with *babul* tree branches to prevent interference of stray animals. There was an initial difference in sites I and II in that the soil in site I was shallow, while the soil in site II was deep and clayey. Advantage of this fact to study the responses of manures to different soil types could not, however, be taken as in site II certain portions of plots did not grow grass on account of depressions in the land in some cases, and presence of bushes and trees in other cases. Due to these causes, statistical analysis was confined to site I only.

Application of manure and harvesting

The different manures used in the experiment were first analysed in the laboratory and the calculated quantities were added to each sub-plot. Each year, farm-

yard manure was applied just before the monsoon by the end of May. Groundnut cake powder, sulphate of ammonia and superphosphate were added after the first two or three showers.

Each year, the ring portion of each sub-plot was first separately harvested and then the grass of the net plot was cut. The produce was kept for drying in the sun for three days in the respective plot after which it was bundled and weighed separately. Representative composite samples for each treatment were then analysed in the laboratory for protein, lime and phosphoric acid contents.

Seasonal data. Table I gives the average monthly rainfall for the four years during which the experiment was conducted.

TABLE I

Average rainfall in inches per month during the experimental period

Year	May	June	July	August	September	October	November	December	Total
1946	0·32	15·51	19·23	9·99	4·56	0·20	2·36	0·03	52·40
1947	*-nil-*	2·17	24·09	28·72	29·16	1·33	*-nil-*	*-nil-*	75·47
1948	*-nil-*	15·17	23·83	10·69	8·98	0·27	8·07	*-nil-*	67·61
1949	*-nil-*	13·34	32·34	16·07	37·66	3·96	*-nil-*	*-nil-*	103·37

In 1946, the rainfall was well distributed and this was reflected in the higher yield of grass during that year. In 1948, the experiment was completely vitiated due to the cyclonic rains which washed away the harvested produce. The cyclone affected the results of the next year also, i.e. of 1949, and hence the results of only two years, 1946 and 1947, are presented in this paper.

RESULTS AND DISCUSSION

Yield data

In Tables II and III are given respectively the analysis of variance and the yields due to treatments for the years 1946 and 1947, separately as well as combined. It will be seen from Table II, that the mean squares due to both main plot treatments (nitrogen) and sub-plot treatments (superphosphate) are both highly significant. Of the interaction nitrogen × phosphate, the component kinds of nitrogen × phosphate is significant showing that response to phosphate is different for the two kinds of nitrogen—farmyard manure and groundnut cake and their mixtures with sulphate of ammonia. The mean squares due to season and the interaction —season × sub-plot treatments— are both highly significant, indicating that not only the average yield of grass is different in the two seasons but the response to superphosphate also is different. This is further evident from Table III wherein it can be seen that the average yield of grass in 1946 was higher by about 25 per cent than that in 1947. This may be due to the more equitable distribution of rainfall during 1946 (*vide* Table I).

(2) Farmyard manure supplying 30 lb. nitrogen per acre

(3) Groundnut cake supplying 30 lb. nitrogen per acre

(4) Farmyard manure plus sulphate of ammonia each supplying 15 lb. nitrogen per acre

(5) Groundnut cake plus sulphate of ammonia each supplying 15 lb. nitrogen per acre

(6) Farmyard manure supplying 60 lb. nitrogen per acre

(7) Groundnut cake supplying 60 lb. nitrogen per acre

(8) Farmyard manure plus sulphate of ammonia each supplying 30 lb. nitrogen per acre

(9) Groundnut cake plus sulphate of ammonia each supplying 30 lb. nitrogen per acre.

It was also decided to study the effect of superphosphate (supplying 40 lb. P_2O_5 per acre) alone and in combination with nitrogen.

Layout of experiment. A split-plot design was adopted for this experiment. The nine main plot treatments consisted of different doses and kinds of nitrogen together with a control of no manure ; each main plot was divided into two sub-plots to one of which superphosphate was applied at random. The randomisation of main plot and sub-plot treatments was carried out in 1946. In subsequent years the sites of the experiments with the relative position of the treatments were kept the same.

Plan of experiments. About 10 acres of land situated in the grass-land area of the Government Dry Stock Farm were selected. All the experimental area could not be laid out in one compact block, hence it was sub-divided into two sites, site I consisting of replications A, B, C and D and site II consisting of replications E, F, G and H. The experimental areas, each of 3·85 acres, for the two sites were marked out separately and within each area all the four replications with their main plots, sub-plots and requisite guard rings were marked. The net area of each sub-plot was 78 ft. × 14 ft. (one *guntha*) ; a ring of six feet was kept all round the plot making the grass sub-plot 90 ft. × 26 ft. Before starting the experiment, the area was fenced with *babul* tree branches to prevent interference of stray animals. There was an initial difference in sites I and II in that the soil in site I was shallow, while the soil in site II was deep and clayey. Advantage of this fact to study the responses of manures to different soil types could not, however, be taken as in site II certain portions of plots did not grow grass on account of depressions in the land in some cases, and presence of bushes and trees in other cases. Due to these causes, statistical analysis was confined to site I only.

Application of manure and harvesting

The different manures used in the experiment were first analysed in the laboratory and the calculated quantities were added to each sub-plot. Each year, farm-

yard manure was applied just before the monsoon by the end of May. Groundnut cake powder, sulphate of ammonia and superphosphate were added after the first two or three showers.

Each year, the ring portion of each sub-plot was first separately harvested and then the grass of the net plot was cut. The produce was kept for drying in the sun for three days in the respective plot after which it was bundled and weighed separately. Representative composite samples for each treatment were then analysed in the laboratory for protein, lime and phosphoric acid contents.

Seasonal data. Table I gives the average monthly rainfall for the four years during which the experiment was conducted.

TABLE I

Average rainfall in inches per month during the experimental period

Year	May	June	July	August	September	October	November	December	Total
1946	0·32	15·51	19·23	9·99	4·56	0·20	2·36	0·03	52·40
1947	*-nil-*	2·17	24·09	28·72	29·16	1·33	*-nil-*	*-nil-*	75·47
1948	*-nil-*	15·17	23·83	10·69	8·98	0·27	8·07	*-nil-*	67·61
1949	*-nil-*	13·34	32·34	16·07	37·66	3·96	*-nil-*	*-nil-*	103·37

In 1946, the rainfall was well distributed and this was reflected in the higher yield of grass during that year. In 1948, the experiment was completely vitiated due to the cyclonic rains which washed away the harvested produce. The cyclone affected the results of the next year also, i.e. of 1949, and hence the results of only two years, 1946 and 1947, are presented in this paper.

RESULTS AND DISCUSSION

Yield data

In Tables II and III are given respectively the analysis of variance and the yields due to treatments for the years 1946 and 1947, separately as well as combined. It will be seen from Table II, that the mean squares due to both main plot treatments (nitrogen) and sub-plot treatments (superphosphate) are both highly significant. Of the interaction nitrogen × phosphate, the component kinds of nitrogen × phosphate is significant showing that response to phosphate is different for the two kinds of nitrogen—farmyard manure and groundnut cake and their mixtures with sulphate of ammonia. The mean squares due to season and the interaction —season × sub-plot treatments— are both highly significant, indicating that not only the average yield of grass is different in the two seasons but the response to superphosphate also is different. This is further evident from Table III wherein it can be seen that the average yield of grass in 1946 was higher by about 25 per cent than that in 1947. This may be due to the more equitable distribution of rainfall during 1946 (*vide* Table I).

TABLE II

Analysis of variance of yield data separately and combined for 1946 and 1947

(per plot)

Year		1946	1947	1946-1947 (combined)	
Due to	D. F.	M. S.	M. S.	D. F.	M. S.
No manure *v/s.* manure	1	6,895·9***	6,320·3***	1	13,209·9***
Doses of nitrogen	1	14,131·3***	3,906·2**	1	16,448·5***
Kinds of nitrogen	3	3,950·3***	1,282·8**	3	4,716·4***
Doses of nitrogen × kinds of nitrogen	3	402·6	1,093·8	3	1,223·4
Main treatments	8	4,260·8***	2,169·5***	8	5,934·7***
Blocks	3	21,119·0	6,442·8	3	24,475·9
Error (*a*)	24	439·3	226·1	24	469·4
Phosphate *v/s.* no phosphate	1	34,322·0***	6,050·0***	1	34,596·0***
Main treatment × phosphate	8(1)	1,510·7*	494·7	8	1,645·7**
Error (*b*)	27	571·9	408·2	27	477·6
Total	71	..	..	71	..
Season				1	45,511·1***
Main treatment × season				8	495·6
Sub-treatment × season				1	5,766·0**
Main treatment × sub-treatment × season				8	361·0
Error (*c*)				54	510·7
Total				143	

(1) Of the interaction components, the interaction kind of nitrogen and phosphate is significant.

TABLE III

Summary of results

(tons per acre)

Year	1946				1947				1946-47			
Due to	No P_2O_5	P_2O_5	Mean	S. E.	No P_2O_5	P_2O_5	Mean	S. E.	No P_2O_5	P_2O_5	Mean	S. E.
No nitrogen	2·60	2·76	2·68		1·99	2·17	2·08		2·30	2·47	2·39	
30 lb. N.												
Farmyard manure	2·88	3·33	3·10		2·58	2·67	2·63		2·73	3·00	2·87	
Groundnut cake	1·93	3·49	2·71		1·88	2·58	2·23		1·91	3·04	2·48	
Farmyard manure + sulphate of ammonia	2·84	3·81	3·32		2·69	2·83	2·76		2·77	3·32	3·05	
Groundnut cake + sulphate of ammonia	2·12	3·38	2·75	0·132	1·96	2·55	2·26	0·095	2·05	2·97	2·51	0·097
60 lb. N.												
Farmyard manure	3·42	3·59	3·50		2·66	2·90	2·78		3·04	3·25	3·15	
Groundnut cake	3·17	3·81	3·49		2·82	3·02	2·92		3·00	3·42	3·21	
Farmyard manure + sulphate of ammonia	3·54	4·19	3·85		2·74	2·77	2·76		3·15	3·49	3·32	
Groundnut cake + sulphate of ammonia	2·57	3·73	3·14		2·15	2·92	2·54		2·37	3·32	3·85	
Mean	2·79	3·57	3·18		2·39	2·71	2·55		2·59	3·14	2·86	
S. E.	0·071				0·060				0·046			

In Table IV is given the response of grass to phosphate and to the different forms of nitrogen employed, both singly and in combination.

TABLE IV

Yield and response due to N and P_2O_5, singly and in combination

Form of nitrogen	Tons per acre				
	No P_2O_5	40 lb. P_2O_5	Response to N alone in absence of P_2O_5 / Percentage increase of Col. 1 over no manure	Response to N over P_2O_5 / Percentage increase of Col. 2 over 40 lb. P_2O_5 alone	Response to P_2O_5 over N / Percentage increase of Col. 2 over Col. 1
	1	2	3	4	5
Farmyard manure	2·885	3·125	25·4	26·5	8·3
Groundnut cake	2·455	3·230	6·7	30·8	31·6
Farmyard manure plus sulphate of ammonia	2·960	3·405	28·7	37·9	15·0
Groundnut cake plus sulphate of ammonia	2·210	3·1	—3·9	27·3	42·3
S. E. for sub-plot P_2O_5 treatments within a mainplot treatment	0·098	..	..	..	..
S. E. for sub-plot treatments in different main plots	0·097	..	..	..	..
Nitrogen	2·299	2·466	..	..	..

Response to nitrogen. From column 3 of Table IV, it will be seen that there is a substantial increase in the yield of grass due to nitrogen alone in the form of a mixture of farmyard manure and sulphate of ammonia giving an increase of 28·7 per cent. This response is further increased to 37·9 per cent in the presence of phosphate (col. 4). Substituting half the nitrogen of the farmyard manure by sulphate of ammonia gives an additional yield of about 10 per cent. However, this does not seem to hold good when half the nitrogen of groundnut cake is given in the form of sulphate of ammonia. On the basis of information collected in the present experiment no valid reasons can be advanced to explain the poor response obtained by application of cake either alone or in mixture with sulphate of ammonia.

Response to phosphate. Addition of phosphate alone gives an increase of seven per cent only over 'no manure'. This response to phosphate is very much higher (Table III, col. 5) in the presence of nitrogen. Further, there seems to be differential

response to phosphate with the different forms of nitrogen used. It is significantly more with nitrogen in the form of cake than in the form of farmyard manure, 31·6 per cent and 8·3 per cent respectively. The latter low response of phosphate may be due to the fairly large quantities of available phosphate in the farmyard manure itself. The response to phosphate is also increased in the presence of sulphate of ammonia.

The responses of the grass to the four forms of nitrogen at two levels, viz. 30 and 60 lb. nitrogen per acre are presented in Table V.

TABLE V

Response to different forms of nitrogen at different levels in the presence of P_2O_5
(tons per acre)

Form of nitrogen	$N+P_2O_5$ *nil*	30 lb. N plus 40 lb. P_2O_5	60 lb. N plus 40 lb. P_2O_5
	1	2	3
Farmyard manure alone	..	3·00 (30·4)	3·25 (41·3)
Farmyard manure plus sulphate of ammonia	..	3·32 (44·3)	3·49 (51·7)
Groundnut cake alone	..	3·04 (32·2)	3·42 (48·7)
Groundnut cake plus sulphate of ammonia	..	2·97 (29·1)	3·32 (44·3)
No manure	2·30	.. ..	.. ..

S. E. for treatment comparisons in the same main plot :—0·138
S. E. for treatment comparisons in different main plots :—0·137
NOTE—Figures in bracket in Table V indicate per cent increase over 'no manure'.

It will be seen that at a level of 30 lb. nitrogen given in a combination of farmyard manure and sulphate of ammonia, the highest increase in yield of 44 per cent over 'no manure' is obtained. The superiority of this combination is maintained at 60 lb. nitrogen level also, where the increase is about 52 per cent. However, the extra yield obtained by doubling the dose of nitrogen is only 8 per cent and hence not economical. Therefore, it may be concluded that the best treatment for manuring grass-lands would be to add 30 lb. of nitrogen supplied equally at 15 lb. nitrogen each of farmyard manure and of sulphate of ammonia along with 40 lb. of phosphoric acid as superphosphate. This treatment will yield 3·32 tons of air-dried grass per acre, an increase of 1·02 tons or 44 per cent over 'no manure' plot.

Botanical observations

Before harvesting, each year, the effect of the manurial treatments on tillering and height of the grasses were recorded at ten random spots in each plot of a replicate separately for each of the four species of grasses namely, *ber*, *moshi*, *phul* and *rohida*. But as all the four species were not always present in all the replications, the observations of individual species were not available for statistical analysis.

However, an examination of the data in general revealed that the addition of phosphate effected a significant increase in the heights of the grasses. Similarly, the combination of farmyard manure and sulphate of ammonia both at 30 lb. and at 60 lb. of nitrogen also significantly increased the height of grasses. It has already

been pointed out that these combinations have also given the highest increase in the yield of grasses.

Nutritive value of the grasses

To study the effect of the different manurial treatments on the nutritive value of the grasses, composite samples of the grasses for each treatment were analysed for their contents of protein, lime and phosphoric acid. The results are given in Table VI.

TABLE VI

Percentage chemical analysis of grass

Form of nitrogen	Crude protein	Lime	Phosphoric acid	Lime-Phosphoric acid ratio
1	2	3	4	5
No nitrogen	2·49	0·380	0·069	5·5
No nitrogen plus super	2·53	0·504	0·152	3·3
30 lb. N				
Farmyard manure	2·58	0·336	0·072	4·7
Farmyard manure plus super	2·67	0·448	0·153	2·9
Groundnut cake	2·94	0·352	0·068	3·2
Groundnut cake plus super	2·98	0·504	0·145	3·5
Farmyard manure and sulphate of ammonia	3·13	0·352	0·071	5·0
Farmyard manure and sulphate of ammonia plus super	3·16	0·476	0·120	3·7
Groundnut cake and sulphate of ammonia	2·66	0·308	0·068	4·5
Groundnut cake and sulphate of ammonia plus super	3·07	0·420	0·153	2·7
60 lb. N				
Farmyard manure	2·97	0·308	0·072	4·3
Farmyard manure plus super	3·16	0·420	0·138	2·7
Groundnut cake	2·97	0·336	0·073	4·6
Groundnut cake plus super	2·94	0·448	0·153	2·9
Farmyard manure and sulphate of ammonia	3·11	0·308	0·091	3·4
Farmyard manure and sulphate of ammonia plus super	3·20	0·420	0·153	2·7
Groundnut cake and sulphate of ammonia	3·07	0·336	0·073	4·5
Groundnut cake and sulphate of ammonia plus super	3·11	0·448	0·126	3·5

Manuring of the grasses has resulted not only in increased yields but also in a much improved nutritive quality. It will be noticed that in all cases, the addition of phosphate has not only increased the phosphoric acid content of the grasses but also the protein and lime content, though to a lesser extent. The larger increases in the phosphoric acid contents of the grasses due to superphosphate is reflected in the lowered CaO/P_2O_5 ratio (last column of Table VI).

The treatment—farmyard manure and sulphate of ammonia giving 30 lb. N. with superphosphate giving 40 lb. P_2O_5—yields the highest increase in protein content. But doubling the dose of nitrogen has not increased the protein content materially.

On the whole, 30 lb. of nitrogen as a mixture of farmyard manure and of sulphate of ammonia with 40 lb. of phosphoric acid as superphosphate would seem to be the best treatment from the viewpoints of both quantity and quality of grass. Due to manuring with this dose on an average, the yield of grass increased from 2·30 tons to 3·32 tons, that of protein from 128 lb. to 235 lb., of lime from 19·6 lb. to 35·4 lb. and of phosphoric acid from 3·6 lb. to 8·9 lb. per acre.

Summary

Preliminary investigations on the manuring of grasses were conducted at the Government Dry Stock Farm at Palghar during the years 1946 to 1949. These experiments were laid out in a split-plot design with 9 main plots—30 and 60 lb. of nitrogen in the forms of farm yard manure, groundnut-cake alone and in combination with sulphate of ammonia and a control 'no manure' plot, while the sub-plot treatments consisted of with and without 40 lb. of phosphoric acid as superphosphate. The findings are as follows :

1. There were four varieties of grasses :—(i) *ber* (*Ischaemum aristatum*, Linn.), (ii) *moshi* (*Iseilema wightii*, Anders.), (iii) *phul* (*Themeda cymbaria*, Hack.) and (iv) *rohida* (*Eulalia argentea*, Brogn.).

2. There was a substantial increase (about 30 per cent) in the yield of grasses due to the application of nitrogen alone, in the form of farmyard manure plus sulphate of ammonia.

3. The response to phosphate alone was of the order of 7 per cent only. But this rose to 23 per cent in the presence of nitrogen.

4. A combination of farmyard manure and sulphate of ammonia each supplying 15 lb. of nitrogen with 40 lb. of phosphoric acid as superphosphate per acre was found to be the best treatment. This yielded 3·32 tons air-dried grass per acre which is higher by 1·02 tons or 44 per cent over the 'no manure' plot.

5. The effect of the above manurial treatment is reflected not only on the yield of the grass but also in its height and its nutritive quality. The protein, lime and phosphoric acid contents of the grasses were increased to the extent of 27, 25 and 74 per cent respectively.

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INFLUENCE OF WEATHER ON THE INCIDENCE OF PADDY GALL-FLY (*PACHYDIPLOSIS ORYZAE*) AT PATTAMBI (SOUTH MALABAR)

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Paddy gall-fly (*Pachydiplosis oryzae*) attacks young paddy shoots and causes what are known as 'silver shoots'. These 'silver shoots' known as *Anai-kombu* in Tamil, *kodu* in Telegu and *Kolathoombu* in Malayalam are the galls in the form of hollow out-growths of paddy stems caused as a result of the irritation by the fly maggot. The minute fly lays its eggs on the young shoots and the maggot that hatches out bores into the stem; due to the irritation thus caused the characteristic galls are formed. These galls do not put forth earheads and ultimately die. In certain years the pest causes appreciable damage to the paddy crop and the loss is estimated to be even up to 20 per cent. This pest is found to occur in Northern Circars, Tanjore, Ramnad, South Kanara and Malabar. In Malabar it is considered to be a minor pest, but in certain years it assumes large proportions and becomes a major pest. This pest is found usually in the 'first crop paddy' (April-May to September-October), seldom in the 'second crop paddy' (October-November to January-February) and never in the 'third or *Punja* crop' (February-March to May). During the first crop season the attack is more in transplanted paddy than in broadcast paddy. Even in the broadcast paddy, the pest is severe in seasons in which the fields get filled up with water as soon as the seeds germinate, without allowing the young seedlings to pass through a short period of drought. The pest is noticed in the first crop paddy nurseries also.

Materials and methods

With a view to study the influence of seasonal factors on the incidence of paddy gall-fly systematic estimations of the incidence of this pest were undertaken from the year 1950 onwards and were compared with meteorological factors. The incidence of the pest was estimated at the Agricultural Research Station, Pattambi, on two varieties, namely PTB. 1 (*Aryan*) and PTB. 5 (*Veluthharikayama*) selected for a Crop Weather Experiment. The varieties were planted at two seedlings per hole with a spacing of 6 in. in lines one foot apart, in A B B A arrangement with six replications. The plots measured 22 ft. × 20 ft. Each plot was divided into two sub-plots and from each sub-plot three samples, each sample containing six bunches, were chosen at random by using Tippet's table. Thus from each plot 36 bunches were selected for observations and the number of shoots attacked and the total number of tillers in each bunch were counted fortnightly. The estimation of the attacked shoots was continued till the pest disappeared. The data on the estimation of the incidence of the pest are given in Table I.

TABLE I

Percentage infestation of paddy gall-fly

Year	Dates of observations	Percentage of attacked shoots on the total number of shoots	
		PTB. 1	PTB. 5
1950	24 July	0·03	0·01
	7 August	0·1	0·1
	21 August	1·0	0·9
	4 September	1·7	1·3
	18 September	0·02	0·01
1951	10 July	0·7	1·1
	24 July	5·6	6·3
	7 August	6·2	5·7
	21 August	5·3	5·3
	4 September	8·4	7·4
	18 September	*-nil-*	*-nil-*
1952	21 July	0·4	0·6
	4 August	5·2	5·8
	18 August	12·4	13·8
	1 September	15·6	13·9
	15 September	5·6	3·7
	22 September	5·1	3·9
	6 October	*-nil-*	*-nil-*

NOTE.—(i) The counting of the galls was commenced as soon as they were seen in the field.

(ii) In all the three years the nurseries were sown in the last week of May or in the first week of June and the seedlings were transplanted in the first or in the early part of second week of July.

From the results it is seen that the percentage of 'silver shoots' goes on increasing till the varieties reach their reproductive phase and the percentage of attack is at the maximum when the varieties reach their maximum tillering phase.

The maximum tillering phase was reached in the first week of September and thereafter there was reduction in the total number of shoots.

Weather observations

It was observed that the symptoms of the pest appear in the first week of July in the transplanted field. So the pest would have started oviposition in the nursery itself. Therefore, for studying the influence of weather on the incidence of paddy gall-fly it is necessary to take into consideration not only the weather factors which prevail after the seedlings are transplanted in the main field, but also the weather factors which prevail when the seedlings are in the nursery. From a study of the weather conditions which prevailed when the seedlings were in the nursery and after they were transplanted, it was possible to gather that a cloudy and rainy weather in the second fortnight of June followed by a bright and warm weather in the first fortnight of July was congenial for the pest to flourish. During the second fortnight of June the seedlings are in the nursery and a cloudy and rainy weather during that period is best suited for the gall-fly to lay eggs. The seedlings infected with the eggs are transplanted in the first or in the early part of the second fortnight of July and a bright and warm weather during this period is congenial for the eggs to hatch out. The meteorological factors gathered during the second fortnight of June and in the first fortnight of July are given in Table II.

TABLE II

Meteorological observations

Observation	Year 1950	Remarks	Year 1951	Remarks	Year 1952	Remarks
			Second fortnight of June			
Mean maximum	84·7°F.	Mainly bright weather with intermittent rains	84·3°F.	Mainly cloudy and rainy weather	84·3°F.	Mainly cloudy and rainy weather
Mean minimum	73·4°F.		72·5°F.		72·6°F.	
Average relative humidity	95 per cent		96 per cent		95 per cent	
Total rainfall	7·75 in.		10·51 in.		13·22 in.	
No. of rainy days	11		12		14	
			First fortnight of July			
Mean maximum	82·8°F.	Mainly cloudy and rainy weather	85·2°F.	Bright and sunny weather with intermittent rains	85·0°F.	Bright and sunny weather with intermittent rains
Mean minimum	72·5°F.		72·8°F.		73·9°F.	
Average relative humidity	96 per cent		95 per cent		92 per cent	
Total rainfall	12·08 in.		4·77 in.		4·30 in.	
No. of rainy days	14		6		7	

Discussion

From a perusal of the incidence of the pest during the years 1950 to 1952, it was found that the attack was very minor in the year 1950 and was serious during the years 1951 and 1952. In the year 1950 when the incidence was very minor, a bright and hot weather prevailed during the second fortnight of June and a cloudy and rainy weather prevailed in the first fortnight of July. On the other hand, in the years 1951 and 1952 when the attack was severe, cloudy and rainy weather prevailed in the second fortnight of June followed by a bright and warm weather in the first week of July. Thus it appears that a squally weather in the second fortnight of June, followed by a bright and warm weather in the first fortnight of July, is congenial for the appearance of the pest while just the opposite state of weather, that is, bright weather in the second fortnight of June and cloudy and rainy weather in the first fortnight of July prevents the appearance of the pest. It is the experience of the local ryots as well as of the Agricultural Research Station that if the rains in the 'Thiruvathera Nattuvela' (which almost synchronizes with the first fortnight of July) fail and a bright weather prevails, there is bound to be an attack of paddy gall-fly. Thus, the foregoing observations corroborates the experience of the cultivators to a great extent.

This study throws some light on the usefulness of meteorological observations to aid the ryots in taking measures in advance, against insect pests which may appear under certain weather conditions. If we are able to find out under what weather conditions particular pests would appear, we would be in a position to forewarn the cultivators to resort to preventive measures against such pests in time.

Summary

1. The incidence of the gall-fly in two varieties of paddy was estimated for three seasons.
2. Weather factors such as maximum temperature, minimum temperature, relative humidity, total rainfall and number of rainy days were studied in order to see how far the incidence of the pest is influenced by climatic conditions.
3. It is tentatively inferred that a cloudy and rainy weather in the second fortnight of June followed by a bright and hot weather in the first fortnight of July brings about high incidence.
4. The possibility of predicting the incidence of a major pest like paddy gall-fly in Malabar from a knowledge of the existing weather conditions is indicated in this paper.

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REVIEWS

PLANNING FARM BUILDINGS

By John C. Wooley

(*Published by McGraw Hill Book Company Inc., New York, 1953, pp. 303, Price $5·0*)

THIS is the third edition of the book, recently revised by Professor Wooley of the University of Mussouri (U.S.A.). In this edition, the important changes relate to a chapter 'Modern Farm Practices in the U.S.A., which affect farm housing'. Some information on appraisal of farm buildings is also included.

This book is meant for providing training to prospective county agents, farm managers and vocational teachers in the U.S.A. The book deals with conditions in the U.S.A., where farming is on a large scale, cheap timber is available for farm buildings, and the methods of construction and design are suitable for weather conditions prevailing in that country. The physical size and physiology of the farm animals taken into account are for those which are used for commercial purposes (in the U.S.A.) such as dairy animals, beef stock, hogs, poultry and sheep.

This type of design and construction of farm buildings, is particularly suited to western countries, where farmers live on the farm individually. In countries like India, where farmers live in communities near about their farms, the American design of farm buildings is of little value. Materials used in the U.S.A. are seasoned wood of a type that is easily workable and available in plenty and the designs are particularly made to suit the weather conditions in the U.S.A. and keeping in view the comfort of the animal from the point of view of ventilation and requirement of space. As many of these are not the same in tropical countries like India, the designs and methods indicated in the book cannot be adopted in India, directly. The only part of India where the American designs of farm buildings could find some use are in Kashmir where climate compares favourably with that in the U.S.A. and cheap timber is available as in the U.S.A. In the past, much thought has not been given for research done in India either on farm buildings or rural housing. This subject requires an entirely different approach in India, due to social conditions of living of the rural people, the local weather and above all, as only locally available raw materials should be used for this purpose. But there are some cases, in which the description and methods may prove useful to Indian conditions with some modifications.

Chapters six, seven and eight relate to the design of dairy buildings. A study of this will be useful for the Government and military dairy farms in India. Chapters on housing of hogs, poultry and sheep are of little use in India at present as large-scale rearing of such animals is not common. There is a chapter on each of the subjects relating to storage for grain and forage and rural utilities such as water supply and sewage. These are of some interest in India, but cannot be directly

adopted. Thus the book is of limited value under Indian conditions. This also shows, that some foreign methods cannot be used in India as they are, and at the same time enough research or investigation has not been done on this subject in India. There is need for data or a hand book, pertaining to rural housing in India to start with. (R.V.R.).

WORLD ECONOMIC REPORT 1951-52

(Published by the United Nations, New York, 1953, pp. 141, Price, \$1·50)

WORLD Economic Report 1951-52, is the fifth in a series of comprehensive reviews of World Economic Conditions published by the United Nations. The report analyses important developments in domestic economic conditions and in international trade and payments during 1951 and 1952. A large mass of data has been assembled and presented which clearly explain some of the important features of the World Economic Situation.

The Report is divided into two parts. Part I of the Report analyses major national economic changes in three groups of countries, *viz.* economically developed private enterpise economies, centrally planned economies and economically under-developed private enterprise economies. Part II analyses changes in international trade and payment of countries which are generally exporters of manufactured products, countries which generally export primary commodities and the countries with centrally planned economies.

The introduction to the report highlights important economic developments during 1951 and 1952 and sets out major problems calling for national and international action. To quote from the Report itself, "the rise in industrial production in the world as a whole continues to reflect great divergences in achievements among individual countries. *Per capita* production of food remains less than before the war, especially in Asia, since the growth of world population has been of the order of 15 per cent. While the danger of inflation is still present in some countries, the problem of maintaining high levels of employment may become of considerable importance in the next few years. Finally, international trade continues to be beset by multifarious restrictions, and international economic balance has yet to be achieved."

The Report examines the areas of continuing economic difficulty under three main heads—problems relating to the maintenance of economic stability, those concerned with persistent disequilibrium in international payments and those arising from the relatively slow advance of the under-developed countries. With regard to the first problem relating to the maintenance of economic stability, the report maintains that "The possibility of deflationary development cannot, of course, be excluded from consideration, though there are many elements supporting demand in the present situation. The major factors which are likely to influence the economic stability are governmental expenditure, private investment, responsiveness of government tax revenues, social security, contributions and social expenditure to changes in the level of activity and employment, fiscal and credit policies of the

government, etc. The Report goes on to say, "Even if it should prove possible to maintain a broad stability in the total demand for goods and services in the industrialised countries, the events of recent years suggest that this, of itself, would not provide immunity from erratic swings in inventory expenditures.............The under-developed countries are especially vulnerable to these fluctuations...... because the primary products which they export are a major component of the inventories of the industrialised countries".

The second area of continuing economic difficulty concerns primarily the direct transactions between the dollar area and the rest of the world on account of the inability of most countries to balance their dollar accounts, without recourse to financial aid from the United States and restrictions on dollar imports. A number of suggestions have been made to resolve this problem. These include (a) increase in world supply of dollars through continuation of the rapid growth of economic activity in the United States tending to increase the demand for imported foodstuff and raw materials, reduction of United States import duties, removal of customs formalities or consolidation of tariff concessions previously granted and outflow of long-term capital and (b) expending the production and exchange between non-dollar countries, of goods which compete with dollar imports, by providing adequate incentive to produce additional supplies of these goods at prices competitive with those produced in the dollar area.

Particular attention has been devoted to the third area of economic difficulty relating to the economic development of under-developed countries. In recent years, while world income has grown rapidly, it is now even more unequally distributed among countries than in the pre-war periods. The problems of under-developed countries include dependence on export of raw materials for a substantial proportion of their income and for the bulk of their foreign exchange receipts, price fluctuations leading to abnormal fluctuations in real income and inadequacy of supplies of food and other consumer goods. Much remains to be done in these countries for the more effective mobilisation of domestic resources for the channelling of those resources to productive activity, and for the strengthening of technical and administrative skills. The Report recommends the need for an expanded flow of capital to under-developed countries, laying emphasis on acceleration of the balanced growth in those areas where it is most needed.

The Report does not make any specific recommendations in respect of centrally planned economies like U.S.S.R., mainland China, etc. However, an important observation made is that the economic links between eastern Europe and mainland China on the one hand and the rest of the world on the other have progressively diminished since pre-war years.

Needless to say that the Report in a brief space deals with nearly all the important economic problems that confront different countries, groups of countries and the world as a whole. The Report should be of great interest to all those who are interested in day-to-day as well as long-term international economic problems.

FARM MECHANIZATION DIRECTORY 1954

COMPILED BY THE STAFF OF THE 'FARM MECHANIZATION'

(Published by the Temple Press Ltd., London, December 1953, pp. 612, Price 21s.)

THIS is the fourth edition of the Directory, which is being published annually by the staff of the *Farm Mechanization* in London. It is a book of reference on British-made agricultural machinery and tractors and also similar equipment of foreign origin available for sale in the U.K. It covers the products manufactured by about 1800 manufacturers and includes tractors, implements, accessories, spare parts for agricultural equipment, including those needed for the dairy, piggery, poultry house, etc. It is useful for farmers, importers, officers of the agricultural departments and even manufactures, who need parts, supplies and spares for agricultural equipment.

No prices of equipment are indicated, as these are likely to fluctuate. There are five parts in the book.

Part 1 deals with organisations in the U.K., both official and non-official, which pertain to agriculture, agricultural engineering, manufacture, distribution and supply of agricultural equipment. This part is particularly useful to foreign visitors to the U.K. for securing information and guidance on the set up in the U.K., for promotion of agricultural engineering.

Parts 2 and 3, deal with tractors built in the U.K. and a few which are made in Germany and the U.S.A., available for sale in that country. Part 3 deals with the tractor test-reports published by the National Institute of Agricultural Engineering in the U.K. This part of the test report is of use to salesmen of agricultural equipment and engineers employed in the design or operation of agricultural tractors. A useful addition, that could possibly be made here, is a non-technical interpretation of the test results and a method of comparison of one tractor from another from the farmers' point of view. Some indications, as to how a farmer can select a tractor to fit his needs will be of further use.

Part 4 which deals with implements, deals very comprehensively on not only agricultural implements but also accessories, supplies and spare parts needed for agricultural equipment. This is useful, for owners of agricultural machinery, for purchasing spares and parts. This section includes, engines, workshop equipments, wind mills, irrigation appliances, pumps, etc. Chapter 5 deals with indices to classification of implements and classification of advertisers.

This Directory deals with mostly British made agricultural machinery and tractors, but India is importing similar equipment from the U.S.A. and other Continental countries. As nearly 50 per cent of our imports of agricultural machinery is from the U.K., this Directory should interest, importers and mechanised farmers in India. (R.V.R.)

INSECTICIDES AND COLONIAL AGRICULTURAL DEVELOPMENT

(Proceedings of the Sixth Symposium of the Colston Research Society held at the University of Bristol in March 1953)

EDITED BY T. WALLACE AND J. T. MARTIN

(Published by Butterworths Scientific Publications, London, 1954, pp. x. & 169, Price 30s.)

THE book forms Volume VI of the Colston Papers as the publications of the Colston Research Society are called. The Society has been organising annual Symposia to cover different fields of learning and has selectd subjects for the purpose which 'possess a reasonably wide appeal, and are at a sufficiently interesting stage of development it make to likely that they will benefit by Symposium treatment'. The subject of insecticides in relation to modern, agricultural practice amply satisfies both these conditions.

The book contains texts of 16 papers, presented at the Symposium, together with reports of discussions on groups of them. The papers deal with investigations on insecticides and their uses in the control of locusts, pests of cotton and other crops, stored products and livestock, requirements, problems and difficulties of applying insecticides in the field and of their supply by manufacturers. Geographically, the scope of the discussions is confined chiefly to the British Colonial territories, lying mainly in the tropics with a total area of about 2¼ million square miles. In an opening address, Dr W. J. Hall, Director, Commonwealth Institute of Entomology, London, provides some interesting factual data about crop production in the British Colonies, losses sustained through pest attacks and the role of insecticides in preventing such losses. He considers and rightly that in many cases it is not possible to assess losses, caused by pests and plant diseases, in terms of their cash value because of the inherent difficulty of isolating the effects of various factors that depress crop yields. However, the figures quoted by Dr Hall must impress anybody with the enormity of the losses. For example, locusts and grasshoppers throughout the world in the decade, 1925-34 were considered responsible for annual losses valued at £15 million.

Of the tropical crops that suffer insect damage, two of the greatest interest to us in India are sugarcane and cotton. Mention is made of the successful control of the sugarcane borer, *Diatrae saccharalis* F., in Barbados during 1929-38 by the liberation of the egg parasite, *Trichogramma minutum* Riley, whose performance against allied borers in India has been less encouraging. In Tanganyika, the boll-worm, *Heliothis armigera*, has been controlled by dusting with a mixture of 10 per cent DDT plus 3 per cent gamma BHC at the rate of 16 lb. per acre 'on from five to seven occasions at ten-day intervals'. Five to seven applications of a dust on the same crop and in the same season to control one pest may be too much for an Indian cultivator.

The paper and discussion on locust control are based largely on the researches carried out by the Anti-Locust Research Centre, London, and experience of control

operations in African countries during the past nine years or so. The methods of control considered have, therefore, been poison baiting, air to ground and air to air spraying and ground spraying. Ground dusting, largely practised in India during the 1939-46 and the present locust cycles, has naturally found no mention, since it is only very recently that ground dusting has begun to be recognised in other countries as being also a satisfactory method of control. An important suggestion made is about the pretreatment of egg-infested grounds with poison bait. This is forestalled by the trials of spraying egg beds with aldrin from the air in East Africa and India during the last three years.

In a discussion on storage pests, Professor J. W. Munro of the Imperial College of Science and Technology deprecates the importance given to the assessment of losses through pest attacks in storage, specially in terms of the cash value of the commodities stored, and suggests the acceptance of the fact that all consumable stores are liable to insect attack and the consideration of the measures to protect them adequately. He, therefore, considers that the urgent need is to use the 'large amount of knowledge about the control of infestation' which already exists. This is indeed sound advice.

Three papers deal with the insect and tick pests and carriers of diseases of livestock and the methods of their control. Among disease carriers, the control of the tsetse fly has been successfully attempted with fixed-winged aircraft in Zululand. However, the helicopter is considered to possess some distinct advantages, 'especially in difficult hilly country where ordinary flying would be too hazardous', because of the 'down-draught from the rotors which would drive the insecticide through a dense leafy canopy to reach the fly'. In the control of insects and ticks of veterinary importance, arsenicals have given way to modern insecticides of which DDT and BHC have been most in use. However, it appears that the residual effect even of such insecticides as aldrin and dialdrin under tropical field conditions does not last for more than a week or so. Secondly, ticks acquired resistance to BHC even within two years and subsequently to other chlorinated hydrocarbons but not to DDT.

Many of the pests discussed are identical with or allied to those that occur in India and many of the methods of control mentioned are already in various stages of development in this country. Likewise, many of the plant protection requirements in India are the same as in the British colonial territories. These include the (i) training of scientific personnel for undertaking or assisting in operational programmes, (ii) operational research or field investigations on various problems of immediate and practical importance, (iii) mechanism for utilising fully the existing knowledge available on pests and plant diseases and the methods of their control and (iv) simple and inexpensive spraying and dusting machines and other equipment, which the small cultivator may effectively use, side by side with the introduction or development of power machines, low volume sprayers, aerial spraying, etc. for large plantations or large-scale control of extensive pest or plant disease outbreaks.

The papers and discussions, brought together in the publication under review, cover a wide variety of plant protection problems and must be of intense interest to plant protection workers in India. (K.B.L.)

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The Editorial Board in its work of examining papers received for publication is assisted in an honorary capacity by a large number of scientists working in various parts of India.

Editorial communications including books and periodicals for review should be addressed to the Secretary, Indian Council of Agricultural Research, Publication Section, New Delhi.

Communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

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Articles intended for *The Indian Journal of Agricultural Science* should be accompanied by short popular abstracts of about 330 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

Reference to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If the reference is made to several articles published by one author in a single year these should be numbered in sequence and the number quoted after year both in the text and the collected references.

If a paper has not been seen in original it is safe to state 'original not seen'. Sources of information should be specifically acknowledged.

As the *format* of the journal has been standardized, the size adopted being crown-quarto (about $7\frac{1}{2}$ in. $\times 9\frac{3}{4}$ in. cut) no text figure, when printed, should exceed $4\frac{1}{2}$ in $\times 5$ in. Figures for plates should be so planned as to fill a crown-quarto page, the maximum space available for figures being $5\frac{1}{4}$ in. $\times 8$ in. exclusive of that for letter press printing.

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